THE ROYAL SOCIETY OF TASMANIA

THE ADVANCEMENT OF KNOWLEDGE

Papers and Proceedings of The Royal Society of Tasmania

Volume 156
December 2022

THE ROYAL SOCIETY OF TASMANIA

THE ADVANCEMENT OF KNOWLEDGE

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Papers and Proceedings of The Royal Society of Tasmania

Edited by Dr Sally Bryant
and published by the Society

Volume 156
December 2022

The Royal Society of Tasmania acknowledges, with deep respect, the traditional owners of this land, and the ongoing custodianship of the Aboriginal people of Tasmania. The Society pays respect to Elders past and present.

We acknowledge that Tasmanian Aboriginal Peoples have survived severe and unjust impacts resulting from invasion and dispossession of their Country.

As an institution dedicated to the advancement of knowledge, the Royal Society of Tasmania recognises Aboriginal cultural knowledge and practices and seeks to respect and honour these traditions and the deep understanding they represent.

Published by
The Royal Society of Tasmania
GPO Box 1166
Hobart, Tasmania, Australia 7000

www.rst.org.au

6 December 2022

ISSN 0080-4703

Cover photograph: Spectacular aurora photographed approx. 7.30 pm 28 May 2017 from the foreshore at Howden, overlooking North West Bay, with a small boat shed in the foreground. Photo copyright Sophie Fazackerley.

Focal Printing
Copy editor Caroline Mordaunt
Typesetting by June Pongratz

PAPERS AND PROCEEDINGS OF THE ROYAL SOCIETY OF TASMANIA

VOLUME 156

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Publication of this volume was generously supported by the Government of Tasmania and the University of Tasmania.

THE ROYAL SOCIETY OF TASMANIA

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DETERMINING THE FATE OF THE CROWTHER STATUE

WARNING: Aboriginal and Torres Strait Islander readers are warned that this article contains references and images of deceased persons and content which may cause distress.

William Lodewyk Crowther (1817–1885), surgeon, naturalist and politician, rose to prominence in Tasmania's early colonial society, including serving a term as Premier of Tasmania (1878–79). His drive and indomitable character made him a popular figure and four years after his death, a monument was erected in Franklin Square, Hobart, in his honour. The unveiling ceremony took place on 9 January 1889 presided over by the Hon. Premier P.O. Fysh and witnessed by a large gathering including members of the government and other distinguished guests (*The Mercury* 9 January 1889, p. 2). Facing towards kunanyi/Mount Wellington, the solid bronze statue was a remarkable likeness and fine piece of work as it towered 8ft 6inches (2.5 m) above its freestone plinth bearing the inscription:

> *"Erected by a grateful public, and sincere personal friends, to perpetuate the memory of long and zealous political and professional services rendered in this colony by William Lodewyk Crowther, F.R.C.S., England, sometime Premier of Tasmania. Born 15th April 1817, died 12th April 1885."*

During the speeches it was prophetic that The Rev. J.W. Simmons, Chairman of the Statue Committee, declared "This memorial may remind future generations that even monuments may perish, but deeds—good or bad—never die." (*Launceston Examiner* 10 January 1889, p. 2)

The Crowther statue has long been a cause of trauma and anger for the Aboriginal people of Tasmania who bear witness to the role Crowther played in the desecration of Aboriginal graves and mutilation of their ancestors. It also speaks to the behaviour of public figures during this period when the quest to procure Aboriginal specimens in the name of science was fuelled as much by personal ambition and ego as scientific curiosity.

The competing rights to obtain the skeleton of William Lanne, whom it was wrongly believed was the 'last' Tasmanian Aboriginal man, began immediately Lanne died on 3 March 1869. Historian Emeritus Professor Stefan Petrow has researched these events (Petrow 1997, pp. 90–112) and records that Dr William Crowther, member of the Royal College of Surgeons, London and Morton Allport, Esq., member of the Royal Society of Tasmania — both made application to Tasmania's Premier Richard Dry as Colonial Secretary, to obtain Lanne's skeleton for their respective institutions. This was a period when Darwin's theory of evolution was fuelling spirited debate by ethnologists, archaeologists, and others on the purported evolution of the human species from a primitive to more superior civilised form, and comparing human bones, particularly skulls, was part of informing this theory.

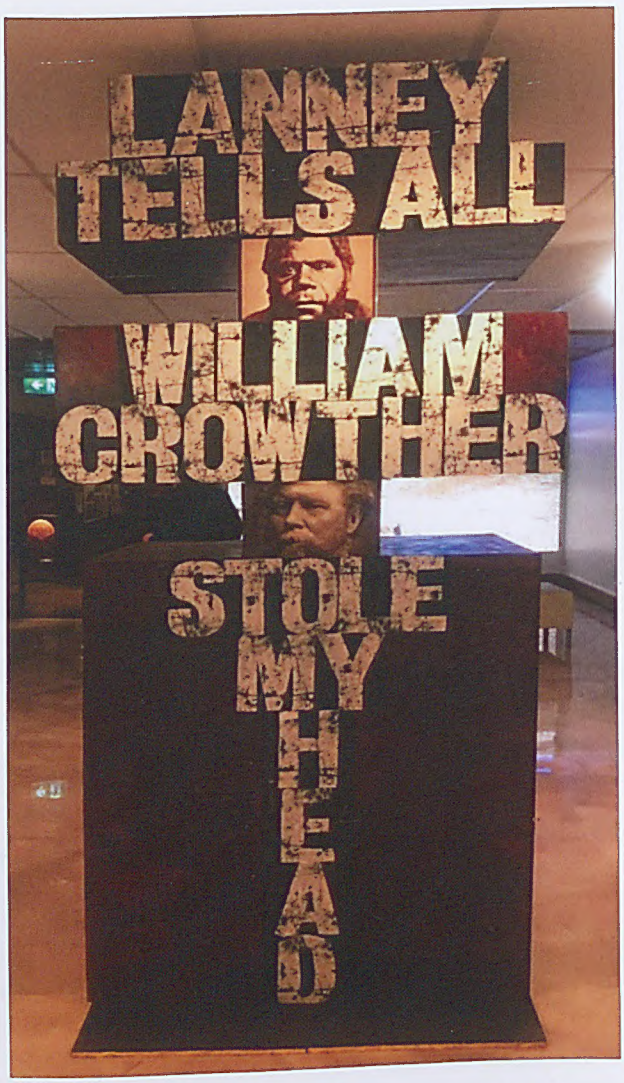
Immediately after Lanne's death, authorisation was given to Morton Allport to obtain Lanne's skeleton but only after Lanne had received a proper Christian burial. On hearing this decision, in a defiant act, Crowther, aided by his son Bingham, secretly went to the morgue and removed Lanne's head, replacing it with that of a white person. Incensed by Crowther's actions, Morton Allport, Dr James Agnew and J.W. Graves (all Royal Society of Tasmania members) aided by Dr George Stokell (Hospital Surgeon), further mutilated Lanne's body before burial by cutting off his hands and feet for the Royal Society Museum.

As news of the mutilation spread, there was public outrage and in the official inquiry that followed, Crowther was dismissed from his honorary position at the hospital. While all those involved were complicit in this abhorrent act, the professional reputations of William Crowther and Morton Allport suffered very little, as both rose to prominence and had statues and museums eventually named in their honour.

Now, as the Commonwealth of Australia moves towards securing an Indigenous Voice to Parliament, States and Territories are exploring their own pathways to truth telling and treaty with our First Nations people. In 2021–22, as part of the Hobart City Council's (HCC) Aboriginal Commitment and Action Plan, the *Crowther Reinterpreted* project was developed (https://www.hobartcity.com.au/Community/Creative-Hobart/Creative-Hobart-projects/Crowther-Reinterpreted). In Stage 1, the HCC invited several highly regarded Tasmanian artists: Allan Mansell, Dr Julie Gough, Jillian Mundy and Professor Greg Lehman who teamed with Tasmanian filmmaker Roger Scholes, to develop works to provoke discussion about the Crowther statue. These works focused on either physically or conceptually reframing the statue itself in Franklin Square, although Lehman and Scholes' 'Lanney Pillar' was later displayed in the Allport Library and Museum of Fine Arts, Hobart. After considering public feedback on Stage 1, Stage 2 of the project was for the HCC to decide on a permanent response to the Crowther monument.

In June 2022, as part of its consultation process, the HCC sought input from the RST on its views as to the fate of the statue. This request was considered firstly by the RST Aboriginal Engagement Committee which then provided the following recommendation to the wider RST Council at their 5 July 2022 meeting: "The RST supports the removal of the statue of William Crowther and the provision of a written interpretation, for example,

William Crowther monument in Franklin Square, Hobart, 13 August 2022. (Photo: S. Bryant)



'Lanney Pillar' by G. Lehman and R. Scholes, in the Allport Library and Museum of Fine Arts, Hobart, 18 May 2022. (Photo: S. Bryant)

a plaque, on the site where the statue now stands." This recommendation derives from commitments made by the RST in its Apology to Tasmanian Aboriginal people delivered in February 2021, and awareness that this statue, erected in 1889, is not appropriate today, and the desire to "advance knowledge" by stimulating discussion of the events and their impacts. A majority of RST Council Members approved the recommendation, and it was sent to the Community, Culture and Events Committee (CCEC), a subcommittee of the HCC.

A report was prepared on the Stage 2 consultation by the Director City Futures, Cultural Programs Coordinator, and the Public Art Coordinator, both of which are under the HCC umbrella.

This report recommended removal of the statue but retention of the plinth and addition of new interpretive elements beside the plinth. The RST was then invited to give a deputation (5-minute verbal presentation) to the CCEC at its meeting on the 4 August, as were Nala Mansell (Tasmanian Aboriginal Centre), Lucy Burke-Smith (Purcell Architects), Isla McGregor representing Dr Ian McFarlane, Louise Elliott, and Professor Greg Lehman. The deputations and ensuing questions from the CCEC explored the widely different opinions expressed. The CCEC then voted unanimously to support the report recommendation to permanently remove the statue. On Monday 15 August the full Council of HCC considered this recommendation. It also voted to support the Report's recommendations to permanently remove the statue, but the vote was not unanimous, seven councillors voting for removal and four voting against.

While the statue's relocation site is still being decided, the HCC Lord Mayor, Councillor Anna Reynolds addressed some of the concerns raised by the public around removal being an attempt to 'erase history' or an example of 'cancel culture'. The mayor responded that "History is not something static. It is a journey. Cities and the communities that inhabit them change over time, as do public priorities and values. "(*The Mercury Newspaper* 10 August 2022, p 24).

Stage 3 of the project is currently underway. The HCC has applied for planning approval to remove the bronze figure of Crowther and store it until a decision is made on its ultimate fate. The plinth will remain in place with

temporary signage explaining the reasons for this action. Stage 4 will involve commissioning interpretive elements for the site including presenting the various, relevant stories of this statue, the people involved, the context of the time and the process by which the statue was removed.

The 4 August meeting is available on YouTube https://www.youtube.com/watch?v=4Ngy2euTL_c. The Report by the Director City Futures, Cultural Programs Coordinator and the Public Art Coordinator can be downloaded from the HCC website at http://hobart.infocouncil.biz/. The RST deputation, presented by the President Prof. Jocelyn McPhie accompanied by PowerPoint slides, is in Appendix 6, page 66 of the Report and transcribed in full below.

My deputation is on behalf of the Council of the Royal Society of Tasmania, of which I am President. I will start with background about the Society because we are not widely known.

The Royal Society of Tasmania is a scholarly organisation modelled on the Royal Society of London and has operated continuously since 1843. The Society established the Royal Tasmanian Botanical Gardens and the Royal Society of Tasmania Museum. The natural history collections were given to the state in 1885 and formed the basis of the Tasmanian Museum that eventually became TMAG.

The Society's modern mission is "the advancement of knowledge". We promote education and research in all disciplines for the benefit of all Tasmanians. We offer public lectures, publish a scholarly journal and books, offer awards to outstanding scholars, and collaborate with other like-minded organisations such as TMAG and UTAS.

The Society was asked by Council officers to comment on the future of the statue of William Crowther. We recommended the removal of the statue from Franklin Square and the provision of a written interpretation on the site where the statue now stands. This position reflects a majority view of members of the Council of the Society and is supported by three reasons.

The first is tied up with the Society's aspiration to develop a respectful relationship with Tasmanian Aboriginal people, a process we began with a formal apology in February 2021.

The Society figured prominently in the events surrounding the dismembering of William Lanne's body and desecration of his grave in 1869. Members of the Society were in fact in competition with Crowther to obtain Lanne's skeleton.

The motivation for both sides was at least partly that Lanne's skeleton should be available for scientific research. Crowther also sought to curry favour with the Royal College of Surgeons in London by providing them with Lanne's skeleton or part of it.

In the same era and later, the Society was involved in obtaining and trading ancestral remains of Tasmanian Aboriginal people and held ancestral remains in the museum without proper care or respect and without permission. The Society also failed to challenge prevailing attitudes and beliefs about Tasmanian Aboriginal people that were misleading and destructive.

It is very clear from Stage 1 of the Crowther Reinterpreted Project that the statue is abhorrent and offensive to the Tasmanian Aboriginal community, in large measure because of Crowther's actions in relation to William Lanne.

The Society is committed to respect the values and perspectives of Tasmanian Aboriginal people and hence, we support removal of the statue.

The second reason relates to the fact that the ethical, moral and social context in Hobart in the 1860's and 70's was different from that of today.

It would have been very difficult for local citizens to see that erecting a statue to William Crowther in the main square in Hobart was an afront to Tasmanian Aboriginal people. Crowther was a well-known, well-educated and influential politician.

Also, in those days, there were few rules governing what could or couldn't be done by doctors to corpses so Crowther's behaviour with respect to William Lanne was then, not entirely unlawful. The knowledge and understanding we have today mean that the statue is now inappropriate.

The last reason is that the Society's mission to "advance knowledge" can be met by the absence of the statue serving as a stimulus for discussion of Crowther's actions and their impacts.

The absence of the statue is likely to be as provocative of critical thought and discussion as its presence, providing that balanced and informative interpretive panels are installed to explain the absence.

Removing the statue does not erase the historic record of Crowther's actions or his life. Removal is an outcome of the inevitable and highly desirable process of a community and its historians critically evaluating ideas about the past. Hence, along with removal of the statue, we support the installation of a balanced and informative commentary in its place as a means of "advancing knowledge".

Finally, I note that the Council officers' proposals being considered at this meeting for Stages 3 and 4 of Crowther Reinterpreted Project are closely similar to Society's recommendation.

Reference: Petrow, S. 1997: The last man: the mutilation of William Lanne in 1869 and its aftermath. *Aboriginal History* 21: 90–112.

Prepared by S. Bryant (Hon. Editor) and J. McPhie (President)

MACROALGAE OF THE SPRING BAY AREA, TRIABUNNA, TASMANIA

by Gerald T. Kraft and Matthew L. Baker

(with eleven plates and two appendices)

Kraft, G.T. & Baker, M.L. 2022 (i:xii) Macroalgae of the Spring Bay area, Triabunna, Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 156: 5–29. ISSN: 0080–4703. Tasmanian Museum and Art Gallery, GPO Box 1164, Hobart, Tasmania 7001, Australia (GTK*, MLB). *Author for correspondence. Email: gtk@unimelb.edu.au

As part of the Tasmanian Museum and Art Gallery's (TMAG) ongoing research, collection-building and nature-discovery program, marine-macroalgal surveys were conducted in late 2019 at the disused woodchip loading wharf at Triabunna and at Louisville Point, on the east and west sides respectively of Spring Bay. Seven taxa are either new to science or new records for Tasmania. The survey, although a brief snapshot in time, significantly expands our knowledge of the macroalgae of the Spring Bay area and provides a baseline inventory to expand upon during future surveys.
Key Words: algal biodiversity, Chlorophyta, Phaeophyceae, Rhodophyta, species discovery, Spring Bay, Tasmania.

INTRODUCTION

The TMAG's annual *Expeditions of Discovery* have, to date, documented the terrestrial flora and fauna of the *Wind Song* property, Little Swanport (Baker *et al.* 2019), and the Musselroe Wind Farm, Cape Portland, Tasmania (Baker *et al.* 2021a). The third expedition, undertaken in the Triabunna area at the Spring Bay Mill site in 2019 (Baker *et al.* 2021b) provided an opportunity to include a marine component for the first time. This additional focus is particularly significant because Triabunna is a port with a history of shipping impacts since visiting ships and their ballast are postulated as having introduced several marine species to Tasmanian waters (Sanderson 1990, Saunders & Withall 2006, Grove *et al.* 2018). The port ceased operations in 2011, but not before at least one major adventive algal species, the kelp *Undaria pinnatifida*, had become established in Australia, presumably in ballast water from Japanese vessels trading at the Spring Bay Wharf (Sanderson 1990). This loading facility remains intact and offers a convenient opportunity to sample vertical transects of 1–12 m on the surface of the wharf pilings, the only sites spanning such a depth range that are easily accessible to shore-based divers.

There have been no prior detailed marine surveys conducted in this area, so the results of this report represent the first inventory to expand upon and enable future comparisons. It should be noted, however, that whereas marine-algal populations have some perennial members, many species are highly seasonal. A single dive excursion and intertidal search do not provide a long-term context for the overall sites. Thus future surveys conducted at different seasons would certainly result in a different complement of species. Finally, the team of five volunteer divers included only one member familiar with the wide variety of algal species present in Tasmanian waters. Although the methodology used to collect specimens was designed to capture all species present, if the dive team had been made up exclusively of specialist phycologists, a larger number of species could be expected. Nevertheless, even with these limitations, several important features of this unique habitat were revealed.

MATERIALS AND METHODS

Collection sites

The Spring Bay Wharf at Triabunna on the east coast of Tasmania, is located at the eastern entrance to Spring Bay, between Freestone Point and Freestone Cove at 42°32'48"S; 142°55'47"E, and consists of a southwesterly-oriented, T-shaped structure, with the stem running 96 m from shore to meet a perpendicular loading dock 235 m in length (pl. 1). The wharf pilings are cylindrical wooden structures in water at maximum pile depths of 6–12 m at the time of the survey. Collections were confined to the pilings because, at the deeper seaward end, the substratum consists of unstable sand and occasional shell debris on which no macroalgae are present. Two teams concentrated on the seaward wharf pilings, whereas a third team entered the water from a 19-m-long structure termed "The Jetty", located 40 m to the northeast in Freestone Cove, where the subtidal rock and non-solid substrata were sampled as well as the shallower, near-shore wharf pilings.

PLATE 1 — The Spring Bay Wharf – stem of the T-shaped wharf where divers surveyed the macroalgal growth on the pilings and surrounding rocks.

The survey of Louisville Point was made from sloping rock with standing-water depressions and shallow crevices just north of the Eastcoaster Resort. Here the intertidal substratum during a 0.5 m low tide was dominated by crustose lichens. As the rock dropped to the water line, the macro-algae were present in sparse and scattered numbers confined to shallow rockpools and clefts, with a band of mostly composed of the leafy green alga *Ulva australis* dominating the permanently submerged shallows at 20–40 cm depths.

Expertise and timing

A team of five scuba divers collected every macro-algal species that they saw at each site on 19 November 2019. A further study was conducted on the western shore opposite the Spring Bay Wharf at Louisville Point on 9 December 2019 to make a representative collection of intertidal and shallow-water species at one site on the other side of the entrance to Spring Bay.

Sampling methods

The wharf survey consisted of two teams of paired divers plus a solo collector who also photographed species. Responsibility for advance planning and safety in the water was under the direction of Divemaster Dr Craig Sanderson. Each diver was given three labelled collecting bags marked "1–3 m", "3–6 m" and "6–12 m", these designating shallow, mid- and lowest-depth ranges. Based on the diver's depth-gauge readings, specimens were collected accordingly. Depth data are important because some species are commonly adapted to particular wavelengths and degrees of light attenuation. Minor effects on species distribution may also be due to differences in wave action, as well as air-exposure times during tidal cycles. Samples were brought to the surface to be sorted, identified and curated. Specimens comprising pressed plant material and diagnostic microscope slides were lodged in the Tasmanian Herbarium (HO). Information from all survey material will be made available on the *Australasian Virtual Herbarium* and the *Atlas of Living Australia.*

Specimen identification

Specimens were identified by the first author based on habit and internal and external characteristics, the former features vouchered by pressing the collections on standard herbarium sheets. Internal cell structures and reproductive bodies were studied from hand-cut sections permanently mounted on slides in Karo™ corn syrup/freshwater/ formalin (25-40/70-55/05%).

Nomenclature and distribution

Nomenclature of algal-taxa follows Guiry and Guiry (2021). Vascular plant nomenclature follows de Salas and Baker (2021).

The geographical ranges given for the species in Appendices 1 and 2 are based primarily on the records published in H.B.S. Womersley's six-volume monographs of "*The Marine Benthic Flora of Southern Australia. Parts I–IIID*" (Womersley 1984, 1987, 1994, 1996, 1998, 2003).

RESULTS

A total of 62 macroalgae taxa from 40 genera was recorded on the Spring Bay Wharf pilings and their immediate surrounding (Appendix 1), as well as on rocks at Louisville Point (Appendix 2). A selection of these is shown in Plates 2–11. The taxa were dominated by species that are endemic to southern Australia (23), with lesser numbers being cosmopolitan (9) or shared primarily with New Zealand (12).

Five taxa were recorded for Tasmania for the first time: brown alga, *Sargassum linearifolium*; and red algae: *Chondria succulenta*, *Dasya divergens*, *Dasythamniella wollastoniana* (pl. 8C) and *Ptilocladia australis* (pl. 9B). A further five taxa are range extensions from the north coast of the state to the south along the east coast: green alga *Cladophora rhizoclonioidea* (pl. 2E); brown algae: *Cystophora polycystidea* (pl. 6C), *Dictyota furcellata* (pl. 4D) and *Sargassum spinuligerum* (pl. 5D); and red alga *Dasya crescens* (Womersley 1984 (*Cladophora*); Womersley 1987 (*Cystophora*, *Dictyota* and *Sargassum*); and Womersley 1998 (*Dasya*)). Two taxa of red algae are either new to science or represent species previously not recorded from southern Australia. These include *Hypnea* sp. (pl. 10C–F), possibly an Indo-Pacific tropical species but difficult to determine from a sterile collection; it is unique in the "lenticular thickenings" of interior cells (pl. 10D, arrows) that no other *Hypnea* species known from southern Australia displays. *Austroclonium?* sp. (pl. 10A, B) is also unlike any described species; its full taxonomic description awaits the collection of reproductive material and DNA sequencing.

Two species of introduced algae were also recorded: brown alga *Undaria pinnatifida* (pl. 5A) and red alga *Grateloupia turuturu* (pl. 7D).

DISCUSSION

A noteworthy finding of the survey is that some species that were expected to be present were not found. In the green algae, it was notable that tubular forms of the genus *Ulva* were totally absent. These types exist as several common species in Tasmania and were previously placed in the genus *Enteromorpha*; they are now included, along with the many leafy forms, in *Ulva*. *Enteromorpha*-type species are among the most common biofouling macro-algae on ships and on farmed shellfish such as mussels and oysters, as well as being abundant on intertidal and shallow-subtidal rocks along open coasts, estuaries and inlets in areas of high human population density throughout Tasmania (Hayden & Waaland 2001, Blomster *et al.* 2002). That they were absent on the wharf suggests that this habitat is likely to be in good condition. Another green alga that is extremely common in most open-coast and estuarine habitats in Tasmania is

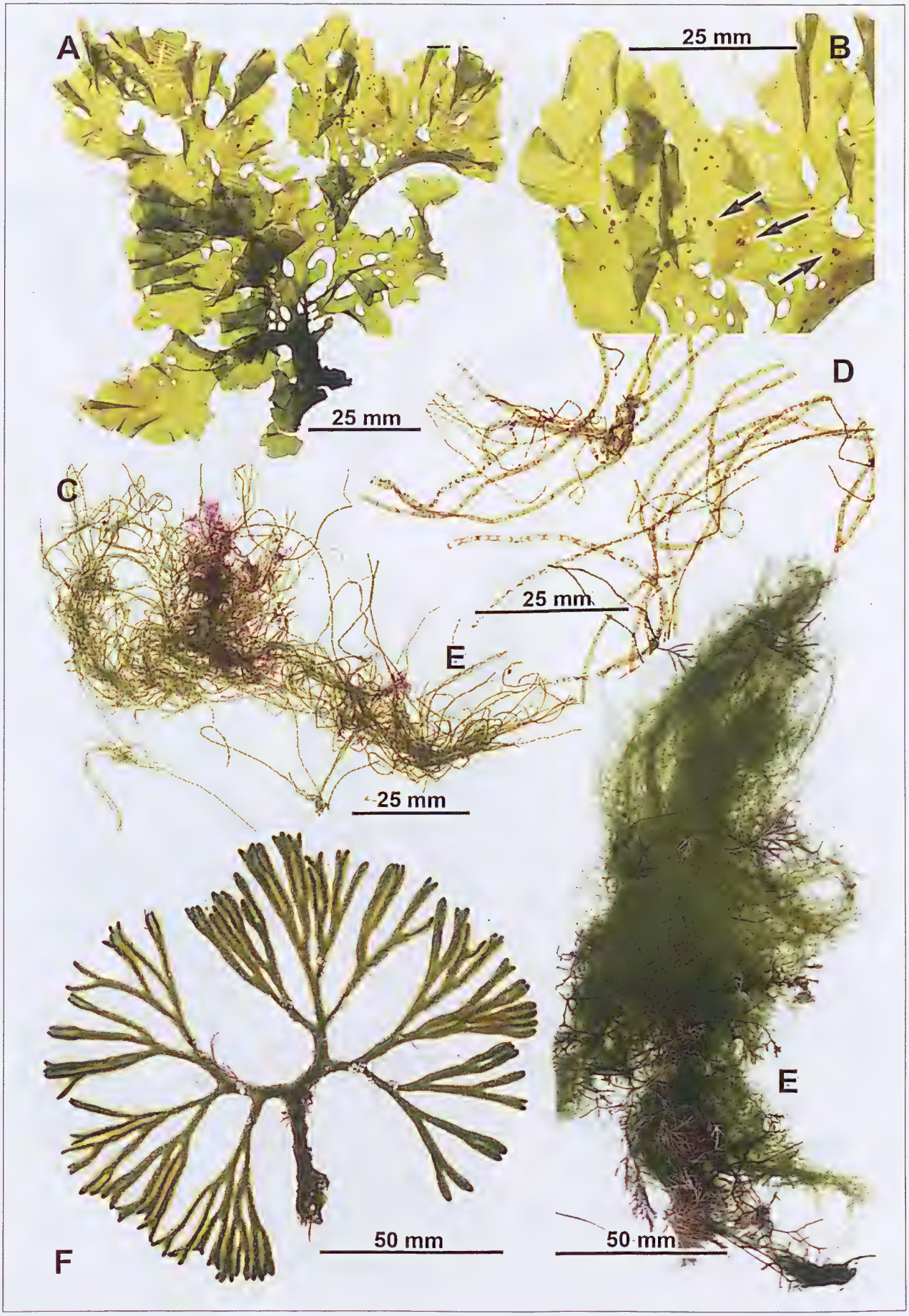


PLATE 2 — Green algae from the Spring Bay Wharf and surrounding rocks (A–D, F) and Louisville Point (E). **A**. *Ulva australis*. **B**. Epiphytic brown alga *Myrionema strangulans* (arrows) on *Ulva australis*. **C**. *Chaetomorpha billardierii*. **D**. *Chaetomorpha coliformis*. **E**. *Cladophora rhizoclonioidea*. **F**. *Codium harveyi*.

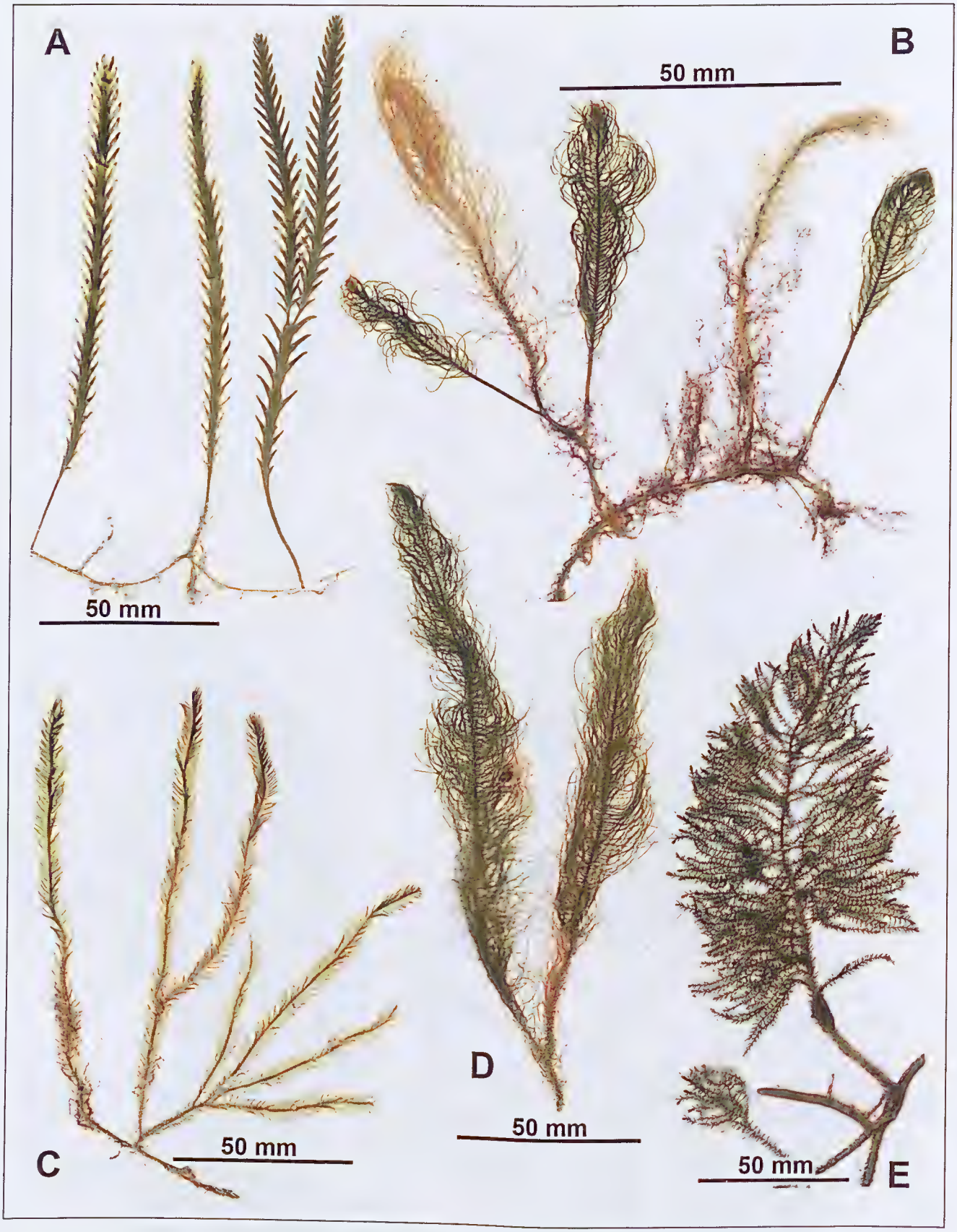


PLATE 3 — Species of the "siphonous" (single-celled) green-algal genus *Caulerpa* from the Spring Bay Wharf pilings and rocks. **A**. *Caulerpa remotifolia*. **B**. *Caulerpa crispata*. **C**. *Caulerpa trifaria*. **D**. *Caulerpa longifolia*. **E**. *Caulerpa flexilis*.

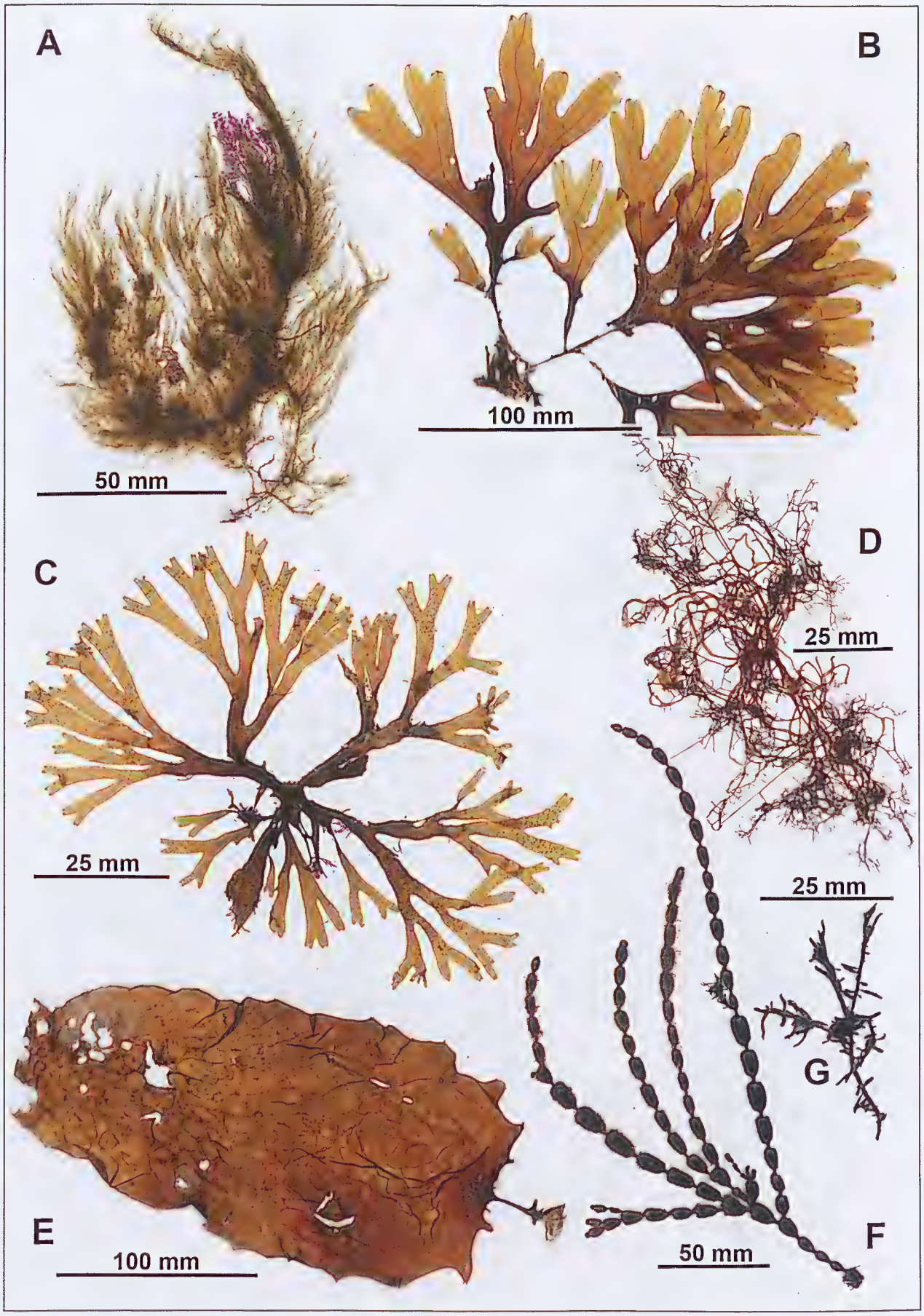


PLATE 4 — Brown algae from the Spring Bay Wharf and surrounding rocks. **A**. *Hincksia sordida*. **B**. *Dictyopteris muelleri*. **C**. *Dictyota dichotoma*. **D**. *Dictyota furcellata*. **E**. *Ecklonia radiata*. **F**. *Hormosira banksii*. **G**. *Notheia anomala*.

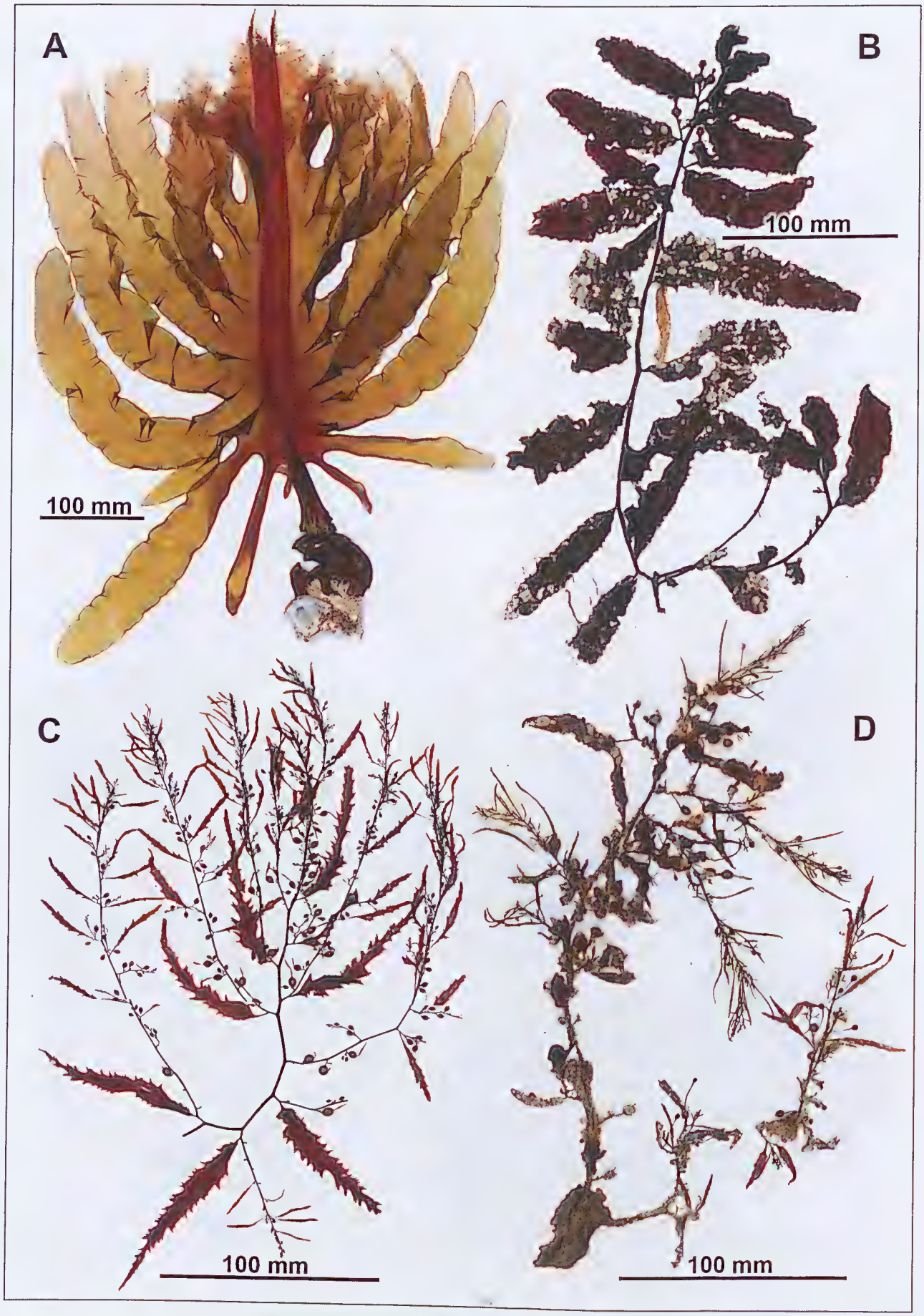


PLATE 5 — Large species of brown algae from the Spring Bay Wharf and surrounding rocks. **A.** *Undaria pinnatifida*. **B.** *Sargassum paradoxum*. **C.** *Sargassum lacerifolium*. **D.** *Sargassum spinuligerum*.

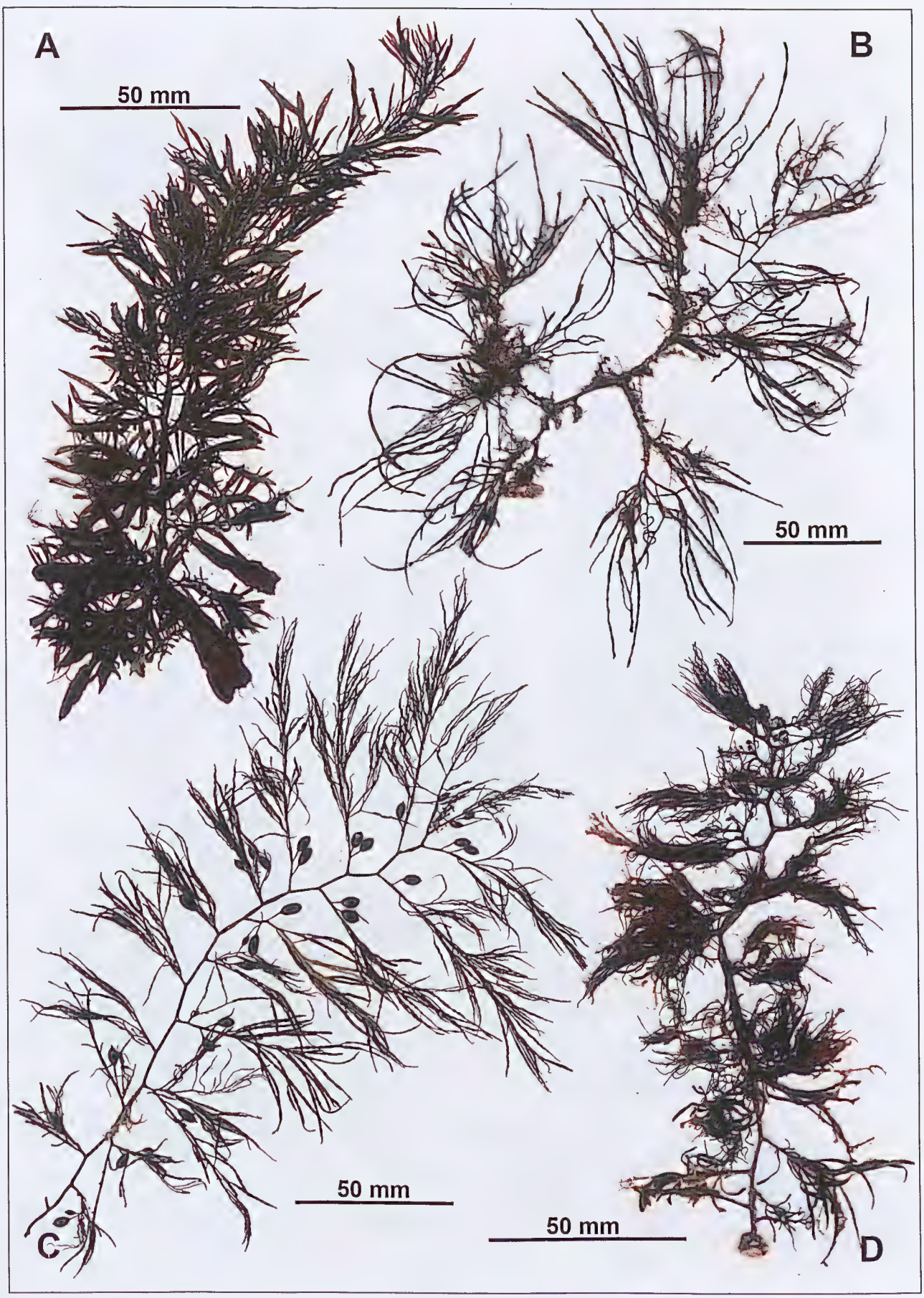


PLATE 6 — Large species of brown algae from the Spring Bay Wharf and surrounding rocks. **A**. *Sargassum fallax*. **B**. *Cystophora retorta*. **C**. *Cystophora polycystidea*. **D**. *Cystophora subfarcinata*.

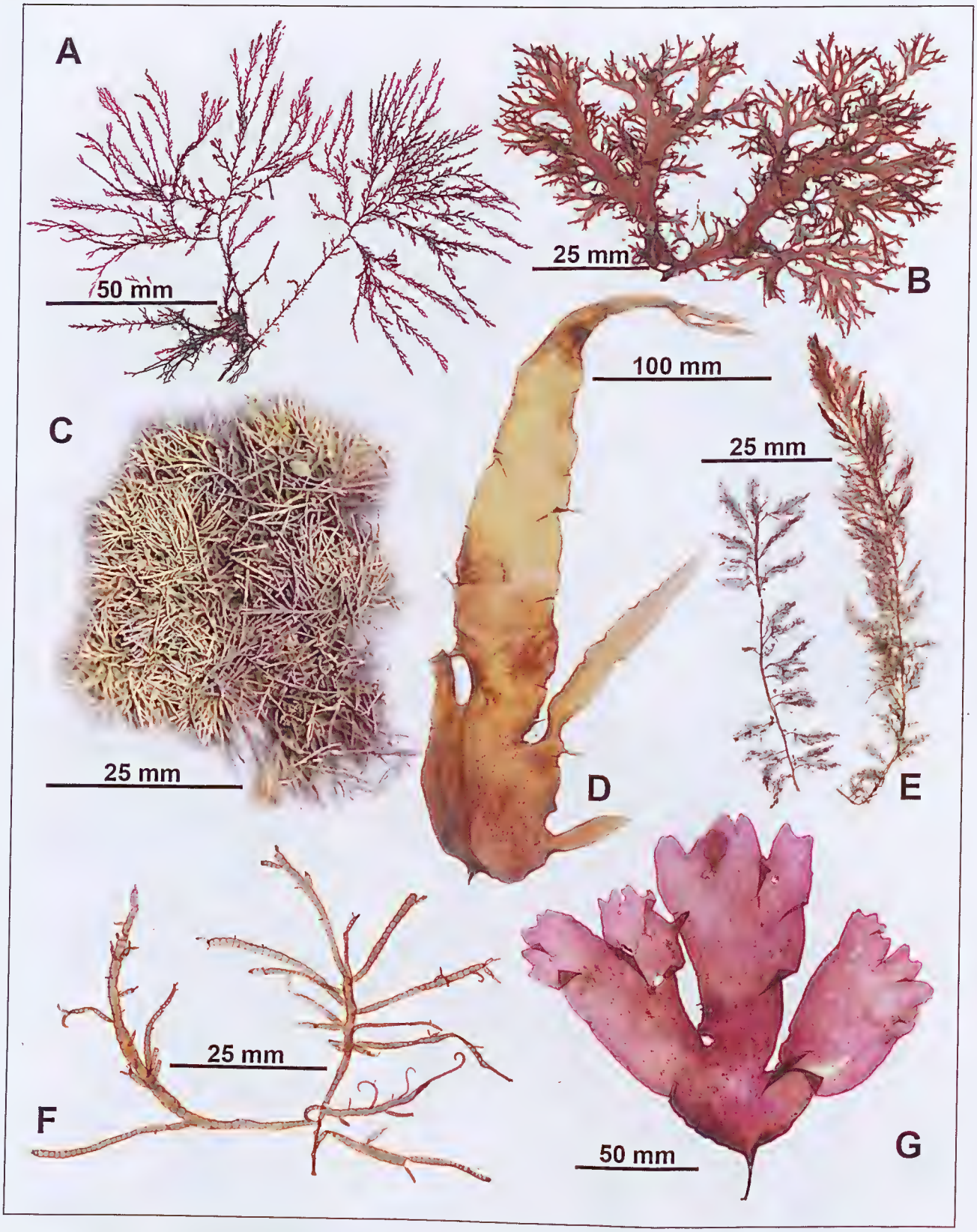


PLATE 7 – Red macroalgae from the Spring Bay Wharf pilings and rocks (A–B, D–G) and rocks at Louisville Point (C). **A**. *Plocamium angustum*. **B**. *Craspedocarpus ramentaceus*. **C**. *Corallina officinalis*. **D**. *Grateloupia turuturu*. **E**. *Asparagopsis armata*. **F**. *Champia affinis*. **G**. Rare *Halopeltis cuneata*.

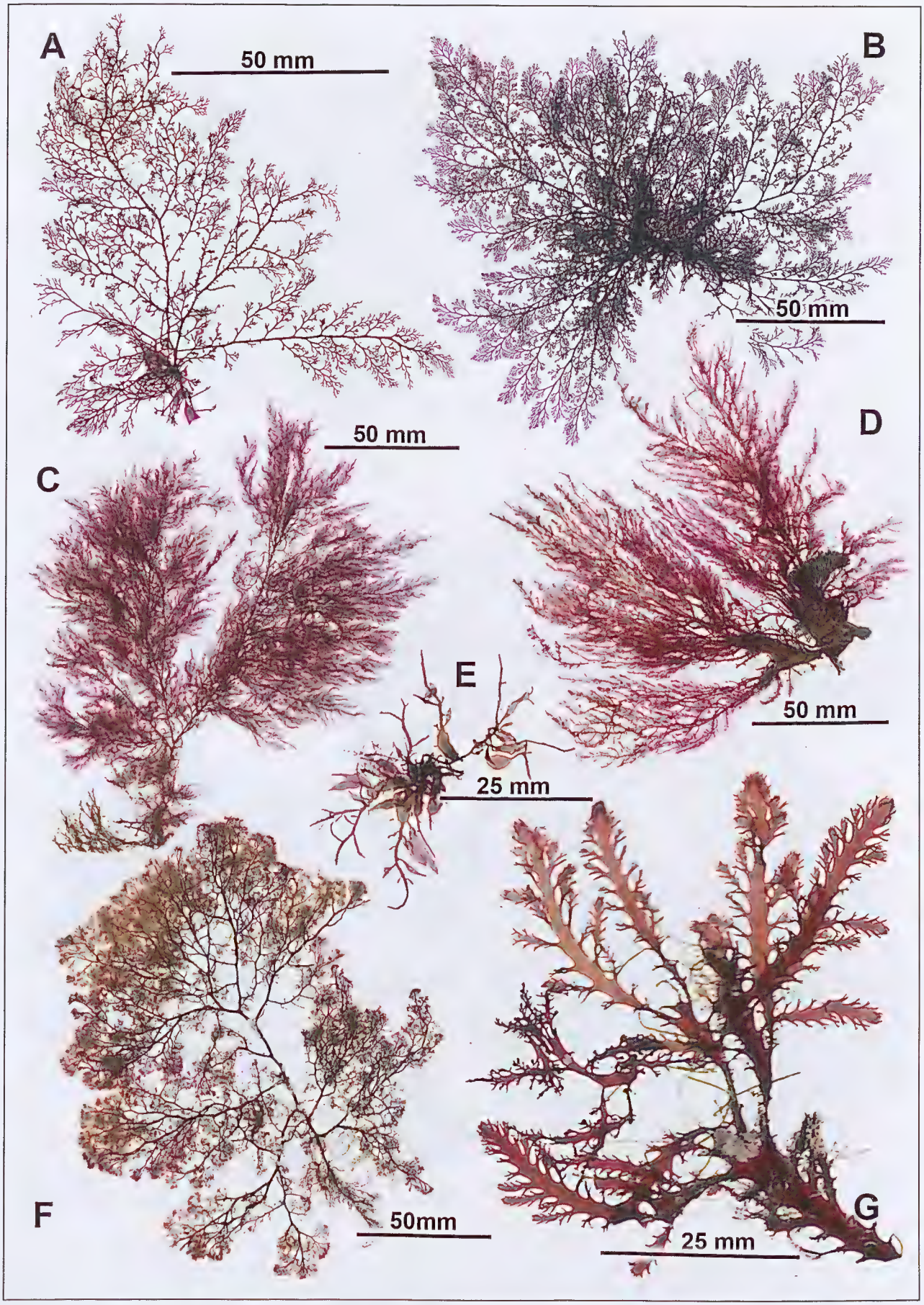


PLATE 8 — Red algae from the Spring Bay Wharf and surrounding rocks. **A**. *Ceramium pusillum*. **B**. *Ceramium lenticulare*. **C**. *Dasythamniella wollastoniana*. **D**. *Dasya villosa*. **E**. *Phycodrys australasica*. **F**. *Heterosiphonia gunniana*. **G**. *Dictyomenia harveyana*.

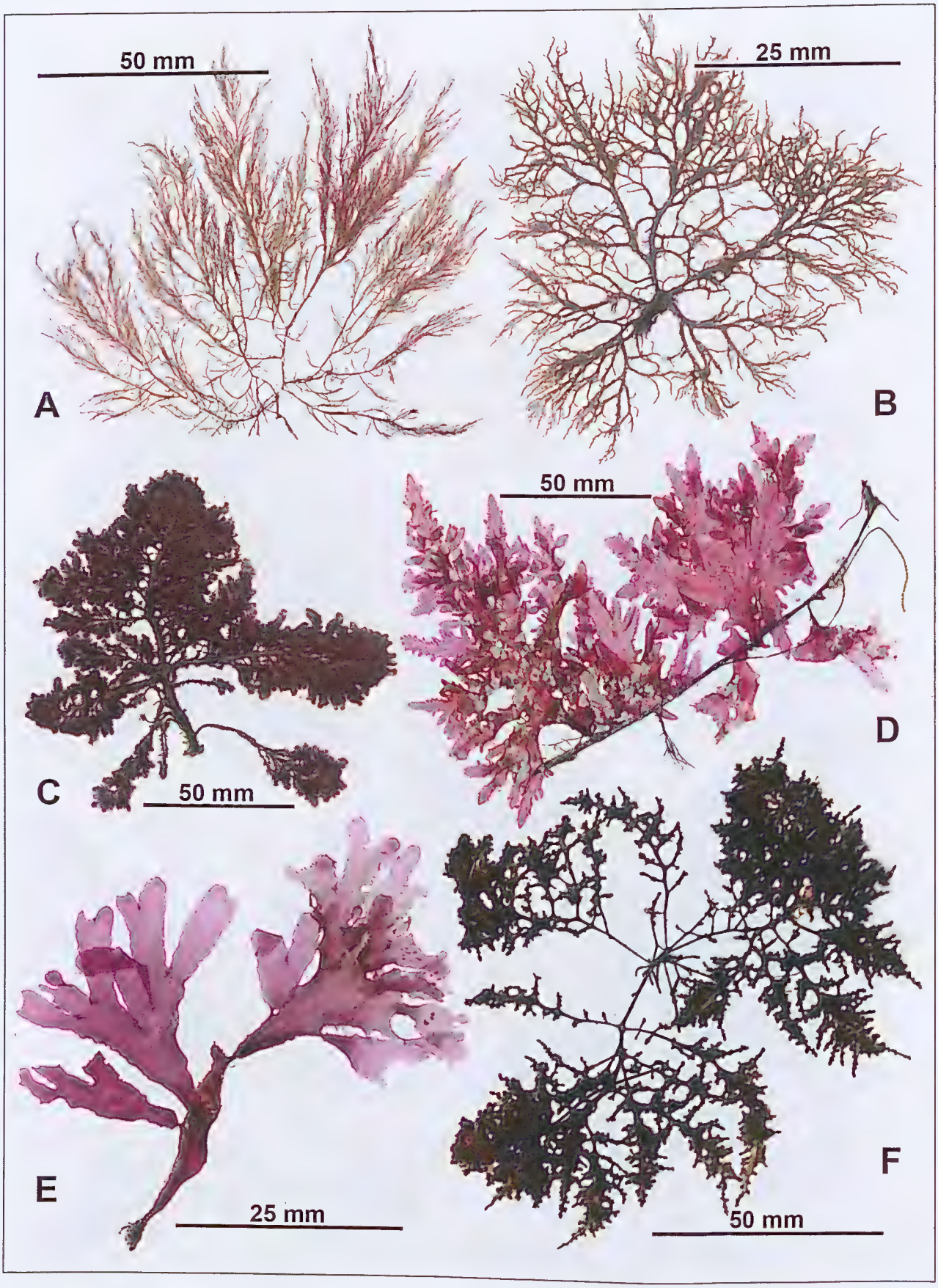


PLATE 9 — Red algae from the Spring Bay Wharf and surrounding rocks (A–B, D–E) and Louisville Point (C, F). **A**. *Spyridia tasmanica*. **B**. *Ptilocladia australis*. **C**. *Lophothamnion hirtum*. **D**. *Hemineura frondosa*. **E**. *Neoharaldiophyllum nottii*. **F**. *Laurencia botryoides*.

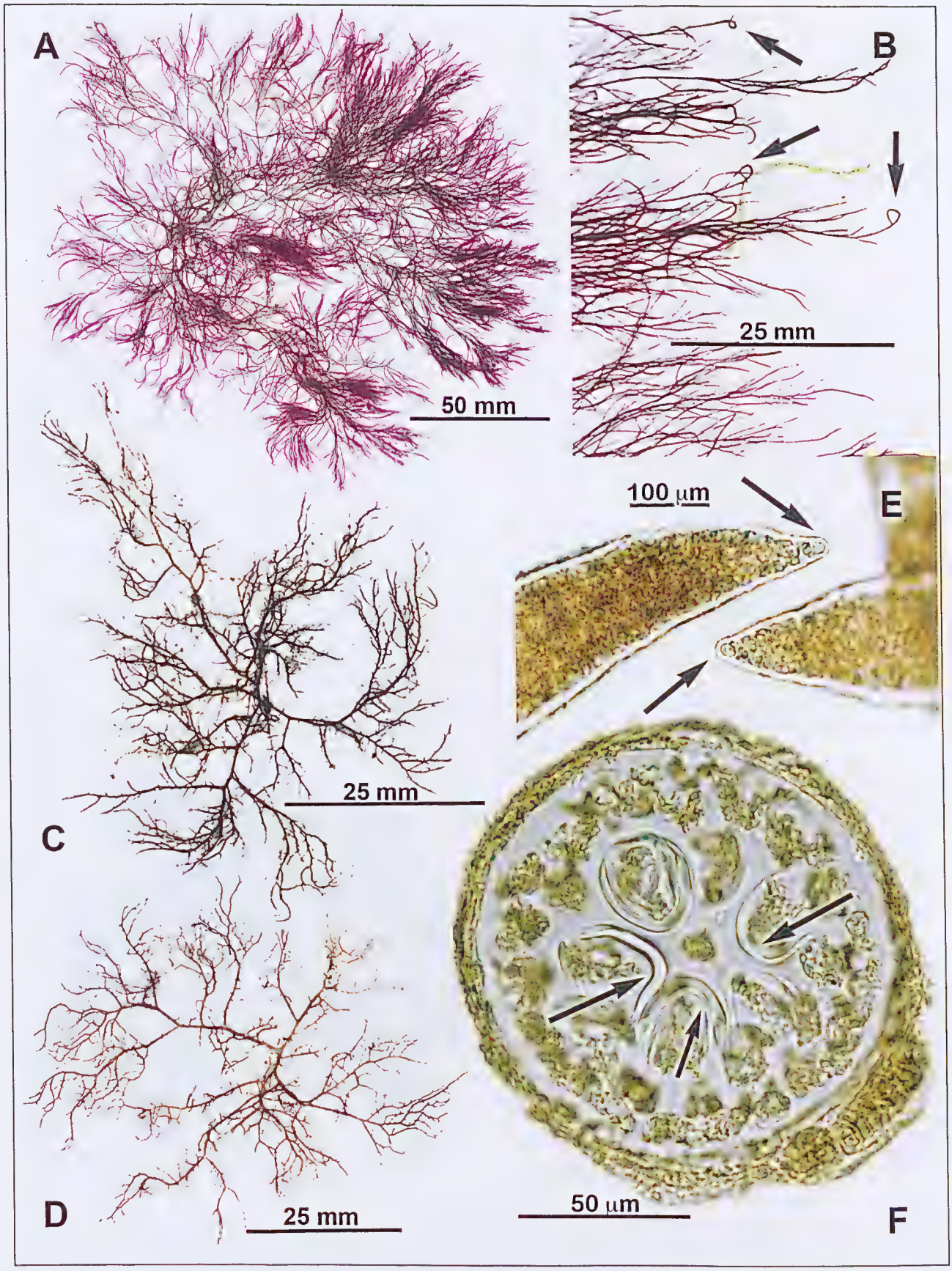


PLATE 10 — Possible new species of red algae from the Spring Bay Wharf and surrounding rocks. (A–B) *Austroclonium? sp. nov.* sp. **A**. Thallus habit. **B**. Tendril hooks (arrows). (C–F) *Hypnea* sp. **C–D**. Pressed habits of the single voucher specimen. **E**. Apices of axes showing uniaxial tips (arrows). **F**. Cross-section showing "lenticular thickenings" of inner cells (arrows) that mark the species as unreported in southern Australia.

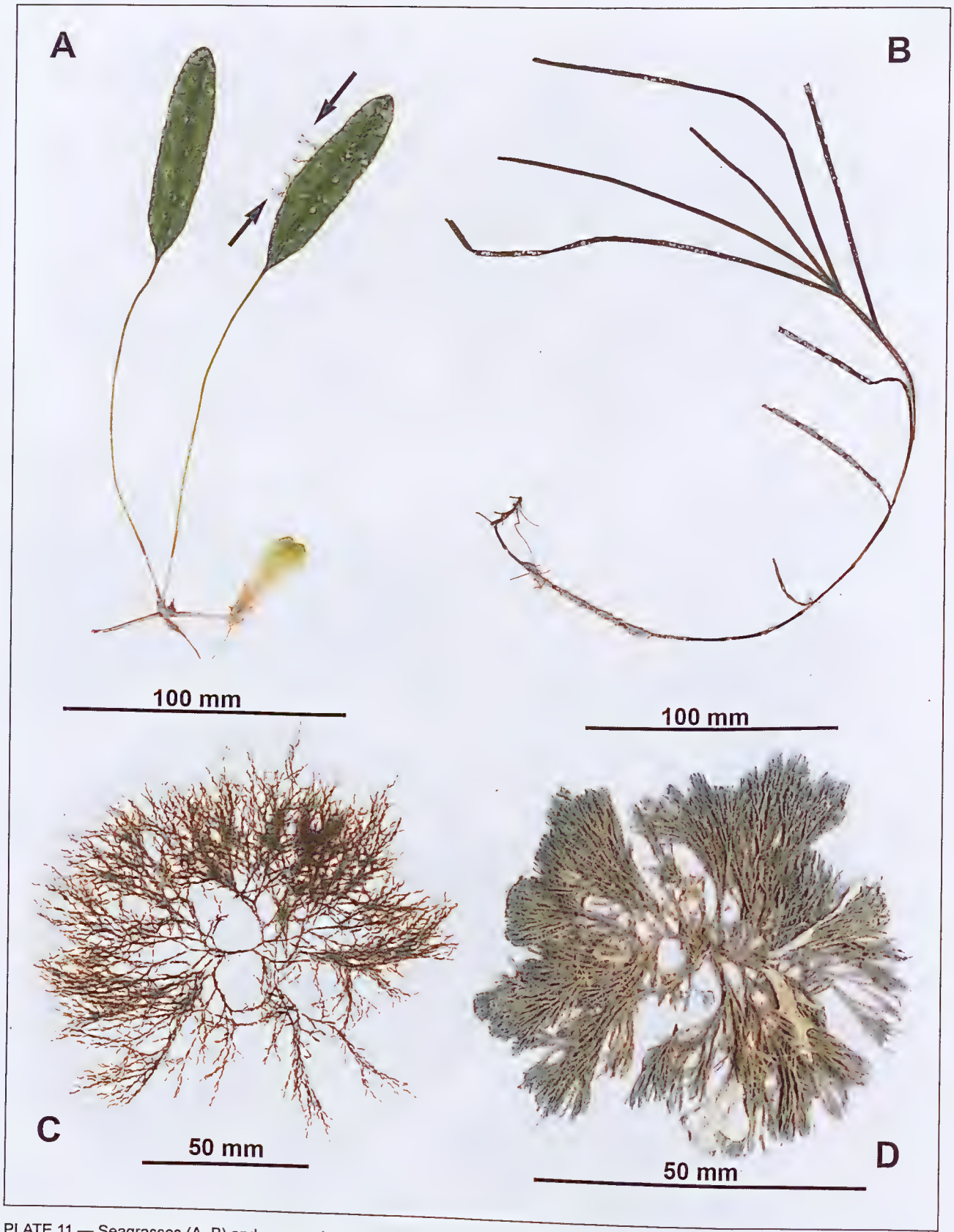


PLATE 11 — Seagrasses (A–B) and seaweed-mimicking invertebrates (C–D) from the shoreward surrounds of the Spring Bay Wharf (A–B) and growing on the seaward pilings of the Spring Bay Wharf (C–D). **A**. *Halophila australis* from sand-floored channels between rocks, the stalked leaves bearing red-algal epiphytes (arrows). **B**. *Zostera muelleri* from shoreward rocks. **C**. An unidentified hydrozoan animal common on the pilings. **D**. The bryozoan *Bugula dentata* from outer pilings.

Codium fragile, which can bloom in great numbers at times and cause damage to fisheries (Trowbridge 1999, Schaffelke & Deane 2005). Not a single thallus of this species was encountered in either the wharf area or at Louisville Point, which was surprising.

In addition to the absence of enteromorphoid forms of *Ulva*, another indicator of unpolluted waters was the scarcity of filamentous brown algae belonging to several genera loosely termed "ectocarps". In polluted or nutrient-enriched habitats, these plants, like the "enteromorphoids", are frequently pioneer colonisers, dominant cover organisms and occasional bloom formers (Womersley 1987). They are also common biofoulers of shipping (Hayden & Waaland 2001). Their scant numbers are a strong indicator that the population of algae on the pilings is a healthy one, or that their absence may be seasonal. The general absence of pioneer colonisers was also noteworthy.

In addition to the macroalgae in the wharf area, two marine flowering plants (angiosperms) were present on and between rocks in shallow waters adjacent to the shoreward pilings. These are the seagrasses *Halophila australis* (pl. 11A) and *Zostera muelleri* (pl. 11B). Both are important primary producers and function in mainland and Tasmanian habitats as stabilisers of loose sediments by means of their horizontal runners and true roots that bind sand and silt (pl. 11A), as buffers against beach erosion, and as substrata for epiphytic algae and invertebrates. In the case of *Halophila*, epiphytes are mainly confined to the blades (pl. 11A, arrows), whereas epiphytes of *Zostera* are concentrated on the woody, lower stalks of the narrowly linear leaves. At the study site, these seagrasses bore very few and only minute epiphytes, which are not documented here.

Invertebrates on the pilings, such as sponges and tunicates, were not within the scope of the study to collect, but the divers did pick two types which, because of their misleading appearances, were at first glance taken for seaweeds. Again, their apparent relative scarcity is indicative of a healthy ecosystem, as pilings that are overgrown, particularly with hydrozoans, are often found in eutrophic waters. Most common was an unidentified hydrozoan (pl. 11C) that hosted some minute epiphytes, and the strikingly blue-green and iridescent bryozoan *Bugula dentata* (pl. 11D), which presented as looking particularly seaweed-like to the divers. Were follow-up studies to be made on the wharf pilings, a specialist of fruticulose (erect growing rather than incrusting) invertebrates would be an important addition to the survey team.

Detailed notes on the specimens are given in the Remarks of Appendices 1 and 2, including the taxonomic authorities for each identified species.

ACKNOWLEDGEMENTS

We would like to thank Robbie Williams of the Spring Bay Mill for access to the site and Tom Wilcox of Tas Marine Construction for permission to access the wharf and to survey the wharf pilings. Rebecca Kraft is thanked for her assistance in organising the survey. Volunteers Michael and Lenanne Isanhart are thanked for their assistance with surveying Louisville Point. We would also like to thank the dive team of Dr Craig Sanderson, Dr Masayuki Tatsumi, postgraduate students Elysha Kennedy and Juliet Kaiser, and cameraman Simon Brooks. Dr Gintaras Kantvilas is thanked for his helpful comments on drafts of the manuscript. Specimens were collected under the permit issued under Section 14 of the *Living Marine Resources Management Act 1995*: 19132.

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APPENDIX 1 — Specimens collected[1] from Spring Bay Wharf, east coast of Spring Bay, Tasmania, Australia 42°32'48"S; 147°55'50"E

Collecting no.	Species	Family	Depth	Collectors	Habitat and remarks
KA 00469	*Ulva australis* Areschoug (1854)	Ulvaceae	3–6 m	S. Brooks	Thalli frequent on pilings of the wharf. The perforate thalli are characteristic of this, the most common leafy green alga in southeastern Tas. **PLATE 2A**
KA 00517 KA 00560	*Ulva australis* Areschoug (1854)	Ulvaceae	1–3 m	J. Kaiser & C. Sanderson	Thalli on nearshore rocks between the wharf and the jetty in Freestone Cove. The perforate thalli are characteristic of this, the most common leafy green alga in southeastern Tas.
KA 00502	*Chaetomorpha billardierii* Kützing (1847)	Cladophoraceae	4–8 m	C. Sanderson & J. Kaiser	A skein of filaments on an assimilator of *Caulerpa longifolia* KA-00503 on a piling of the wharf. This is the first record of this rarely reported species south of its type locality, Georgetown. Otherwise only known from one place in SA.
KA 00575	*Chaetomorpha billardierii* Kützing (1847)	Cladophoraceae	1–4 m	J. Kaiser & C. Sanderson	Filaments tangled in *Heterosiphonia gunniana* and other attached algae on a wharf piling. The commonest unbranched green in Tas. It occurs across southern Australia.
KA 00559	*Chaetomorpha billardierii* Kützing (1847)	Cladophoraceae	1–4 m	J. Kaiser & C. Sanderson	Unattached filaments tangled in attached algae and bryozoans on rocks between the wharf and the jetty in Freestone Cove. The commonest unbranched green in Tas. It occurs across southern Australia. **PLATE 2C**
KA 00482	*Chaetomorpha billardierii* Kützing (1847)	Cladophoraceae	6–10 m	S. Brooks	Unattached filaments tangled in attached algae and bryozoans on rocks between the wharf and the jetty in Freestone Cove.
KA 00558	*Chaetomorpha coliformis* (Montagne) Kützing (1849)	Cladophoraceae	1–4 m	J. Kaiser & C. Sanderson	Unattached filaments mixed with *Chaetomorpha billardierii* tangled in attached algae on rocks between the wharf and the jetty in Freestone Cove. Filaments composed of barrel-shaped to globular cells make up this, the largest *Chaetomorpha* species in Australia. **PLATE 2D**

Appendix 1 cont.

Collecting no.	Species	Family	Depth	Collectors	Habitat and remarks
KA 00561	*Chaetomorpha coliformis* (Montagne) Kützing (1849)	Cladophoraceae	1–3 m	C. Sanderson & J. Kaiser	Thallus growing on a nearshore rock between the wharf and the jetty in Freestone Cove. This species is usually basally anchored to solid substrata.
KA 00522	*Codium harveyi* P.C.Silva (1956)	Codiaceae	1–3 m	C. Sanderson & J. Kaiser	A small thallus on a rock between the wharf and the jetty in Freestone Cove. A species recorded from Shark Bay, WA, to Lake Macquarie, NSW. Previously only known in Tas. from the north coast. **PLATE 2F**
KA 00448	*Codium harveyi* P.C.Silva (1956)	Codiaceae	1–3 m	C. Sanderson & J. Kaiser	A large thallus on a rock between the wharf and the jetty in Freestone Cove. The thallus host large numbers of the epiphytic red alga *Ceramium cliftonianum* (KA 00540). A first record from eastern Tas.
KA 00564	*Caulerpa crispata* (Harvey) G.Belton & Gurgel (2019)	Caulerpaceae	1–3 m	J. Kaiser & C. Sanderson	Thallus growing on nearshore rocks between the wharf and the jetty in Freestone Cove. This species from southern Australia is recently elevated from being a form of *Caulerpa longifolia.* **PLATE 3B**
KA 00520	*Caulerpa crispata* (Harvey) G.Belton & Gurgel (2019)	Caulerpaceae	1–3 m	C. Sanderson & J. Kaiser	Thallus growing on nearshore rocks between the wharf and the jetty in Freestone Cove. Harvey (1859) described this as a distinct species (Harvey 1858—1863), Womersley made it a form of *Caulerpa longifolia* in 1956, and Belton & Gurgel just re-established it as a good species based on molecular evidence (Belton *et al.* 2019).
KA 00521	*Caulerpa flexilis* J.V.Lamouroux ex C.Agardh (1823)	Caulerpaceae	1–3 m	C. Sanderson & J. Kaiser	A large thallus growing on nearshore rocks between the wharf and the jetty in Freestone Cove. A common species on rocks in both southern Australia and NZ from barely subtidal to 40 m depths. **PLATE 3E**
KA 00562	*Caulerpa longifolia* C.Agardh (1823)	Caulerpaceae	1–4 m	J. Kaiser & Craig Sanderson	Thalli growing on rock and on wharf pilings. Among the first Australian seaweed species to be named, it ranges from WA to Vic. and around Tas. **PLATE 3D**
KA 00504	*Caulerpa remotifolia* Sonder (1853)	Caulerpaceae	4–8 m	C. Sanderson & J. Kaiser	Thalli growing on a wharf piling. A common species from mostly sheltered bays from SA to Vic. and around Tas. The sole Tasmanian prior record is by Womersley (1984) of a 1935 collection from Spring Bay.
KA 00519	*Caulerpa remotifolia* Sonder (1853)	Caulerpaceae	1–3 m	C. Sanderson & J. Kaiser	Thalli growing on nearshore rocks between the wharf and the jetty in Freestone Cove. A southern Australian-endemic species. **PLATE 3A**
K 000561	*Caulerpa remotifolia* Sonder (1853)	Caulerpaceae	1–4 m	J. Kaiser & C. Sanderson	Thalli growing on nearshore rocks between the wharf and the jetty in Freestone Cove. This is most often a calm-water indicator species.
KA 00518 KA 00563	*Caulerpa trifaria* Harvey (1863)	Caulerpaceae	1–4 m	C. Sanderson & J. Kaiser	Thalli growing on nearshore rocks between the wharf and the jetty in Freestone Cove. A common species from WA to Westernport and around Tas., usually in moderately calm and sheltered water. **PLATE 3C**

Appendix 1 cont.

Collecting no.	Species	Family	Depth	Collectors	Habitat and remarks
KA 00455; slide KA 00455a	*Hincksia sordida* (Harvey) P.C.Silva (1987)	Ectocarpaceae	1–3 m	S. Brooks	Thalli growing in a dense cluster on a piling of the wharf. A common species worldwide, this specimen particularly nice; non-reproductive. **PLATE 4A**
KA slide 00488	*Hincksia sordida* (Harvey) P.C.Silva (1987)	Ectocarpaceae	3–6 m	S. Brooks	Thalli growing in lax skeins on a wharf piling. Filaments non-reproductive.
KA slide 00456	*Feldmannia mitchelliae* (Harvey) H.-S.Kim (2010)	Acinetosporaceae	1–3 m	S. Brooks	Thallus epiphytic on *Ceramium rubrum* on a piling of the wharf. A worldwide species; thallus is non-reproductive.
KA 00469 (the host pressing)	*Myrionema strangulans* Greville (1827)	Myrionemataceae	3–6 m	S. Brooks	Minute epiphytes growing on blades of *Ulva australis* Areschoug. Named very early on from Scotland, this tiny epiphyte occurs on most ocean shores of both hemispheres.
KA 00471	*Dictyota dichotoma* (Hudson) J.V.Lamouroux (1809)	Dictyotaceae	3–6 m	S. Brooks	A single thallus on a piling of the wharf. A species recorded worldwide. Thallus is heavily antheridial (male). **PLATE 4C**
KA 00569	*Dictyota furcellata* (C.Agardh) Greville (1830)	Dictyotaceae	1–3 m	J. Kaiser & C. Sanderson	Tangled narrow oogonial (female) axes on nearshore rocks between the wharf and the jetty in Freestone Cove. The slenderest *Dictyota* species, found all over Australia. Only a few, north coast records from Tas. to date. **PLATE 4D**
KA 00472	*Dictyopteris muelleri* (Sonder) Reinbold (1899)	Dictyotaceae	3–6 m	S. Brooks	A single mature thallus on a wharf piling. The commonest member of its genus along the whole of southern Australia. **PLATE 4B**
KA 00505	*Dictyopteris muelleri* (Sonder) Reinbold (1899)	Dictyotaceae	5–10 m	C. Sanderson & J. Kaiser	A single, partly senescent thallus on a wharf piling. The most common and largest *Dictyopteris* species in southern Australia.
KA 00474	*Undaria pinnatifida* (Harvey) Suringar (1873)	Alariaceae	3–6 m	S. Brooks	A mature reproductive thallus on a wharf piling. This is the invasive species thought to have been introduced to Australia from Japan by woodchip ships loading at the Spring Bay Wharf. **PLATE 5A**
KA 00473	*Ecklonia radiata* (C.Agardh) J.Agardh (1848)	Alariaceae	3–6 m	S. Brooks	A mature blade, minus its holdfast, from a wharf piling. The kelp species with the widest distribution and depth range of any macro-alga in Australia.
KA 00483	*Ecklonia radiata* (C.Agardh) J.Agardh (1848)	Alariaceae	6–10 m	S. Brooks	A mature blade, minus its holdfast, from a wharf piling. The kelp species with the widest distribution and depth range of any macro-alga in Australia.
KA 00506	*Ecklonia radiata* (C.Agardh) J.Agardh (1848)	Alariaceae	5–10 m	C. Sanderson & J. Kaiser	An intact young thallus with stipe and holdfast from a wharf piling. A kelp species also variable in blade shape. **PLATE 4E**

Appendix 1 cont.

Collecting no.	Species	Family	Depth	Collectors	Habitat and remarks
KA 00523a, b	*Hormosira banksii* (Turner) Decaisne (1842)	Hormosiraceae	1–3 m	C. Sanderson & J. Kaiser	Thallus growing on a nearshore rock between the wharf and the jetty in Freestone Cove. This is a signature Australia and NZ monotypic genus, ranging from Albany, WA, to Norfolk Island. **PLATE 4F**
KA 00524	*Notheia anomala* Harvey & Bailey (1851)	Notheiaceae	1–3 m	C. Sanderson & J. Kaiser	Thallus an obligate epiphyte on *Hormosira banksii* from nearshore rocks between the wharf and the jetty in Freestone Cove. The sole member of its family, this species shares the Australia/NZ distribution of its host. **PLATE 4G**
KA 00527a, b KA 00565	*Cystophora polycystidea* Areschoug *ex* J. Agardh (1848)	Sargassaceae	1–3 m	C. Sanderson & J. Kaiser	Thallus growing on nearshore rock between the wharf and the jetty in Freestone Cove. Appears to be the furthest southern record in Tas.; ranges from Albany, WA, to NSW and only north coast of Tas. **PLATE 6C**
KA 00525	*Cystophora retorta* Areschoug ex J.Agardh (1848)	Sargassaceae	1–3 m	C. Sanderson & J. Kaiser	Thallus growing on nearshore rock between the wharf and the jetty in Freestone Cove. A common tidepool and shallow-subtidal species from WA to Wilsons Promontory and around Tas. **PLATE 6B**
KA 00526	*Cystophora subfarcinata* (Mertens) J.Agardh (1848)	Sargassaceae	1–3 m	C. Sanderson & J. Kaiser	Thallus growing on nearshore rock between the wharf and the jetty in Freestone Cove. The commonest species of its large genus in southern Australia. **PLATE 6D**
KA 00528	*Sargassum fallax* Sonder (1845)	Sargassaceae	1–3 m	C. Sanderson & J. Kaiser	Thallus growing on nearshore rock between the wharf and the jetty in Freestone Cove. Among the commonest *Sargassum* species across southern Australia and around Tas. **PLATE 6A**
KA 00529	*Sargassum lacerifolium* (Turner) C.Agardh (1820)	Sargassaceae	1–3 m	C. Sanderson & J. Kaiser	Thallus growing on nearshore rock between the wharf and the jetty in Freestone Cove. First collected from the Tamar Estuary, the species ranges from SA to NSW and around Tas. **PLATE 5C**
KA 00567	*Sargassum linearifolium* (Turner) C.Agardh (1820)	Sargassacee	1–3 m	J. Kaiser & C. Sanderson	Thallus heavily epiphitised by *Polysiphonia decipiens*. From nearshore rock between the wharf and the jetty in Freestone Cove. Recorded from WA to NSW, but never with certainty from Tas.; probably the first confirmed record.
K 00530	*Sargassum paradoxum* (R.Brown ex Turner) Gaillon (1828)	Sargassaceae	1–3 m	C. Sanderson & J. Kaiser	Thallus growing on nearshore rock between the wharf and the jetty in Freestone Cove. The largest southern Australian species of its large genus. Ranges from SA to Westernport, Vic., and around Tas. **PLATE 5B**
KA 00566	*Sargassum paradoxum* (R.Brown ex Turner) Gaillon (1828)	Sargassaceae	1–4 m	J. Kaiser & C. Sanderson	The basal leaves minus the holdfast and distal parts of a thallus growing on nearshore rock between the wharf and the jetty in Freestone Cove. Because upper and lower parts of *Sargassum* species can differ, they were often given separate species names by early European botanists who only received fragments.

Appendix 1 cont.

Collecting no.	Species	Family	Depth	Collectors	Habitat and remarks
KA 00568	*Sargassum spinuligerum* Sonder (1845)	Sargassaceae	1–3 m	J. Kaiser & C. Sanderson	Thallus growing on nearshore rock between the wharf and the jetty in Freestone Cove. Only a few north-coast records are known from Tas.; mostly a Western Australian species. Probably the first record from southeastern Tas. **PLATE 5D**
KA 00507	*Asparagopsis armata* Harvey (1855)	Bonnemaisoniaceae	5–10 m	C. Sanderson & J. Kaiser	Non-reproductive gametophytes growing on a seaward piling of the wharf. A common species native to southern Australia but now also known from Europe, Chile & NZ.
KA 00531	*Asparagopsis armata* Harvey (1855)	Bonnemaisoniaceae	1–3 m	C. Sanderson & J. Kaiser	A cystocarpic (female gametophytic) thallus growing on nearshore rocks between the wharf and the jetty in Freestone Cove. A common species native to southern Australia but now also known from Europe, Chile & NZ. **PLATE 7E (left- hand specimen)**
KA 00569	*Asparagopsis armata* Harvey (1855)	Bonnemaisoniaceae	1–4 m	J. Kaiser & C. Sanderson	Non-reproductive gametophytes growing on a seaward piling of the wharf. A common species native to southern Australia but now also known from Europe, Chile & NZ. **PLATE 7E (right-hand specimen)**
KA 00536a; KA 00536b	*Hypnea*, possible new species	Hypneaceae	1–3	C. Sanderson & J. Kaiser	A single sterile thallus growing on rocks between the wharf and the jetty in Freestone Cove. A species not known in southern Australia; either new or a tropical species at a record high latitude. **PLATE 10C–F**
KA 00484	*Austroclonium*?, probable new species	Cystocloniaceae	6–9 m	S. Brooks	A sterile thallus from a seaward piling of the wharf. Plants like this not seen before, distinguished by lack of a stalk and by frequent hooks at ends of branches.
KA 00490	*Austroclonium*?, probable new species	Cystocloniaceae	6–9 m	M. Tatsumi & E. Kennedy	A sterile thallus from a seaward piling of the wharf. Plants like this not seen before, distinguished by lack of a stalk and by frequent hooks at ends of branches. **PLATE 10A**
KA 00534	*Austroclonium*?, probable new species	Cystocloniaceae	1–3 m	C. Sanderson & J. Kaiser	A sterile thallus from rocks between the wharf and the jetty in Freestone Cove. Plants like this not seen before, distinguished by lack of a stalk and by frequent hooks at ends of branches. **PLATE 10B**
KA 00571	*Austroclonium*?, probable new species	Cystocloniaceae	1–4 m	J. Kaiser & C. Sanderson	A sterile thallus from rocks between the wharf and the jetty in Freestone Cove. Plants like this not seen before, distinguished by lack of a stalk and by frequent hooks at ends of branches.
KA 00491	*Craspedocarpus ramentaceus* (C.Agardh) Min-Thein & Womersley (1976)	Cystocloniaceae	5–9 m	M. Tatsumi & E. Kennedy	A cystocarpic thallus growing on an outer piling of the wharf. Cystocarps are immature. A species endemic to southern coasts of Australia, including Tas.

Appendix 1 cont.

Collecting no.	Species	Family	Depth	Collectors	Habitat and remarks
KA 00570a; KA 00570b	*Craspedocarpus ramentaceus* (C.Agardh) Min-Thein & Womersley (1976)	Cystocloniaceae	1–4 m	J. Kaiser & C. Sanderson	Sterile thallus epiphytic on *Dasya villosa* on nearshore rocks between the wharf and the jetty. Cystocarps are immature. A species endemic to southern coasts of Australia, including Tas. **PLATE 7B**
KA 00508	*Plocamium angustum* (J.Agardh) Hooker f. & Harvey (1847)	Plocamiaceae	5–10 m	M. Tatsumi & E. Kennedy	A sterile thallus-fragment caught up in other algae on a far piling of the wharf. A common species in southern Australia and the North Island of NZ.
KA 00535	*Plocamium angustum* (J.Agardh) Hooker f. & Harvey (1847)	Plocamiaceae	1–3 m	C. Sanderson & J. Kaiser	A sterile thallus from nearshore rocks between the wharf and the jetty in Freestone Cove. The narrowest of several southern Australian species of the large genus. **PLATE 7A**
KA 00475a, b	*Grateloupia turuturu* Y.Yamada (1941)	Halymeniaceae	3–6 m	S. Brooks	Large cystocarpic blades on pilings of the wharf. This is the most common recently introduced red macroalga in southeastern Australia; thought to be introduced to Tas. from Japan.
KA 00532a, b	*Grateloupia turuturu* Y.Yamada (1941)	Halymeniaceae	1–3 m	C. Sanderson & J. Kaiser	Large thalli growing on a rock between the wharf and the jetty in Freestone Cove; KA 00532b senescent, lacking base. This is the most common recently introduced red macroalga in southeastern Australia; thought to be introduced to Tas. from Japan. **PLATE 7D**
KA 00533a, b	*Grateloupia turuturu* Y.Yamada (1941)	Halymeniaceae	1–3 m	C. Sanderson & J. Kaiser	Juvenile fronds from rocks between the wharf and the jetty in Freestone Cove. This is the most common recently introduced red macroalga in southeastern Australia; thought to be introduced to Tas. from Japan.
KA 00572	*Champia affinis* (Hooker f. & Harvey) Harvey (1853)	Champiaceae	1–4 m	J. Kaiser & C. Sanderson	A single thallus from a rock between the wharf and the jetty in Freestone Cove. An endemic species characterised by diaphragms and terminal hooks. **PLATE 7E**
KA 00476, sheet and slide	*Rhodymenia leptophylla* J.Agardh (1878)	Rhodymeniaceae	3–6 m	S. Brooks	A cluster of juvenile thalli on an outer piling of the wharf. Originally named from NZ, this species is widespread there and across temperate and subtropical Australia.
KA 00492	*Halopeltis cuneata* (Harvey) G.W.Saunders (2010)	Rhodymeniaceae	5–10 m	S. Brooks	A single sterile thallus on an outer piling of the wharf. Probably an endemic Tasmanian species, relatively rare and unreported. **PLATE 7G**
KA 00460	*Ceramium virgatum* Roth (1797)	Ceramiaceae	1–3 m	S. Brooks	A single cystocarpic thallus on an outer piling of the wharf. Worldwide; one of the first macroalgae named; was commonly known as *Ceramium rubrum* C. Agardh.
KA 00539	*Ceramium isogonum* Harvey (1855)	Ceramiaceae	1–3 m	C. Sanderson & J. Kaiser	Tetrasporangial thalli epiphytic on *Cystophora retorta* on nearshore rocks between the wharf and the jetty in Freestone Cove. Widespread in southern Australia although Womersley (1998) questions its presence in Tas.
KA 00478a, b; slide	*Ceramium excellens* J.Agardh (1894)	Ceramiaceae	3–6 m	S. Brooks	Heavily tetrasporangial thalli growing on a piling of the wharf. Originally named from the mouth of the Tamar River, recorded from SA to Vic. and Tas.

Appendix 1 cont.

Collecting no.	Species	Family	Depth	Collectors	Habitat and remarks
KA 00494a, b	*Ceramium excellens* J.Agardh (1894)	Ceramiaceae	5–10 m	M. Tatsumi & E. Kennedy	Tetrasporangial thalli among turf algae on a piling of the wharf. Originally named from the mouth of the Tamar River, recorded from SA to Vic. and Tas.
KA 00540	*Ceramium cliftonianum* J.Agardh (1876)	Ceramiaceae	1–3 m	C. Sanderson & J. Kaiser	Thalli heavily epiphytizing *Codium harveyi* on nearshore rocks between the wharf and the jetty in Freestone Cove. A widespread species first described from Perth area and occurring eastwards to NSW and around Tas.
KA 00493	*Ceramium pusillum* Harvey (1863)	Ceramiaceae	5–10 m	M. Tatsumi & E. Kennedy	A single tetrasporangial thallus on an outer piling of the wharf. A beautifully patterned alga from southern Australia, Tas. and NZ. **PLATE 8A**
KA 00477; slide 00477	*Ceramium lenticulare* Womersley (1978)	Ceramiaceae	3–6 m	S. Brooks	A single cystocarpic thallus on an outer piling of the wharf. A very uncommon recently described species recorded from one site each in SA, Vic. and Tas. (Port Arthur). **PLATE 8B**
KA 00537a; KA 00537b	*Ptilocladia australis* (Harvey) Wollaston (1968)	Ceramiaceae	1–3 m	C. Sanderson & J. Kaiser	Thallus epiphytic on the stems of the seagrass *Zostera muelleri* from nearshore rocks between the wharf and the jetty in Freestone Cove. Recorded from Shark Bay to Walkerville, Vic., this appears to be the first record from Tas.
KA 00578	*Ptilocladia australis* (Harvey) Wollaston (1968)	Ceramiaceae	1–3 m	J. Kaiser & C. Sanderson	Thallus growing on a nearshore rock between the wharf and the jetty in Freestone Cove. Recorded from Shark Bay to Walkerville, Vic., this appears to be the first record from Tas. **PLATE 9B**
KA 00513; 00513 slide	*Antithamnion delicatulum* (Harvey) De Toni (1903)	Ceramiaceae	5–10 m	M. Tatsumi & E. Kennedy	Sterile thalli from an algal turf on a seaward piling of the wharf. Widespread in southern Australia, also Lord Howe Island, South Africa, Bangladesh & New Caledonia.
KA 00526a	*Antithamnion hanovioides* (Sonder) De Toni (1903)	Ceramiaceae	1–3 m	C. Sanderson & J. Kennedy	Thalli epiphytic on *Cystophora subfarcinata* (KA 00526) on a rock between the wharf and the jetty in Freestone Cove. The most common species of a large genus; ranges from WA to NSW and around Tas.
KA 00541	Callithamnioid?	Callithamniacee	1–3 m	C. Sanderson & J. Kaiser	Turf components on nearshore rocks between the wharf and the jetty in Freestone Cove. Does not match anything recorded from Tas.; specimen is completely sterile.
KA 00542	*Spyridia tasmanica* (Kützing) J.Agardh (1852)	Callithamniacee	1–3 m	C. Sanderson & J. Kaiser	A large sterile thallus growing on nearshore rocks between the wharf and the jetty in Freestone Cove. First named from Georgetown, it ranges from WA to NSW, but only one other collection besides the type is recorded from Tas. (Bruny Island). **PLATE 9A**
KA 00485; KA 00485 slide	*Dasythamniella wollastoniana* (Harvey) Womersley (1998)	Wrangeliaceae	6–9 m	S. Brooks	A single large thallus growing on a hydrozoan on an outer piling of the wharf. A rarely recorded species from WA to Vic.; this appears to be the first record from Tas. **PLATE 8C**

Appendix 1 cont.

Collecting no.	Species	Family	Depth	Collectors	Habitat and remarks
KA 00495a, b; slide KA 00495a	*Medeiothamnion protensum* (Harvey) E.M.Gordon (1972)	Wrangeliaceae	5–10 m	M. Tatsumi & E. Kennedy	A sterile thallus on an outer piling of the wharf. Distinctive in leaching the red pigments from its cells on pressing; endemic to Australia SA, Vic. & Tas.
KA 00537a–c	*?Ptilothamnion schmitzii* Heydrich (1893)	Wrangeliaceae	1–3 m	C. Sanderson & J. Kaiser	Sterile thalli growing among turf algae on rocks between the wharf and the jetty in Freestone Cove. Very hard to tell exactly what these are from just sterile filaments; a provisional ID only.
KA slide 00458	*Spongoclonium* sp?	Wrangeliaceae	1–3 m	S. Brooks	A tetrasporangial thallus fragment among turf algae on a wharf piling. Not enough of the plant to make for a confident ID.
KA 00459; KA 00459 slide	Unidentified genus and species of the tribe Monosporeae	Wrangeliaceae	1–3 m	S. Brooks	A thallus fragment among turf algae on a wharf piling. Soft and flaccid filaments with scalpelliform apical cells; not like any species treated in Womersley (1998).
KA 00547a, b	*Polysiphonia decipiens* Montagne (1842)	Rhodomelaceae	1–3 m	S. Brooks	Thalli epiphytic on *Cystophora retorta* on nearshore rocks between the wharf and the jetty in Freestone Cove. The most common species of a very large genus from southern Australia, NZ and subantarctic Auckland Island.
KA 00576	*Polysiphonia decipiens* Montagne (1842)	Rhodomelaceae	1–4 m	J. Kaiser & C. Sanderson	Thalli epiphytic on *Sargassum linearifolium* KA 00567 from a nearshore rock between the wharf and the jetty in Freestone Cove. The most common species of a very large genus from southern Australia, NZ and subantarctic Auckland Island.
KA 00465	*Lophurella periclados* (Sonder) F.Schmitz (1897)	Rhodomelaceae	1–3 m	S. Brooks	Thallus growing on a piling of the wharf. A common low-intertidal to shallow subtidal species in S.E. Australia and NZ.
KA 00481a, b	*Lophurella periclados* (Sonder) F.Schmitz (1897)	Rhodomelaceae	3–6 m	S. Brooks	Thalli growing on a piling of the wharf. A common low-intertidal to shallow subtidal species in S.E. Australia and NZ. Few records from >2 m depths.
KA 00499	*Dictyomenia harveyana* Sonder (1853)	Rhodomelaceae	6–10 m	M. Tatsumi & E. Kennedy	A large cystocarpic thallus on an outer piling of the wharf. An Australian endemic from WA to NSW and around Tas. One of the largest red algae in the State. **PLATE 8G**
KA 00548	*Dictyomenia harveyana* Sonder (1853)	Rhodomelaceae	1–3 m	C. Sanderson & J. Kaiser	A large sterile thallus from a rock between the wharf and the jetty in Freestone Cove. An Australian endemic from WA to NSW and around Tas. One of the largest red algae in the State.
KA 00549	*Chondria succulenta* (J.Agardh) Falkenberg (1901)	Rhodomelaceae	1–3 m	C. Sanderson & J. Kaiser	A fragment of a tetrasporangial thallus from a nearshore rock between the wharf and the jetty in Freestone Cove. Only a fragment, but the sporangia and vegetative features match this species recorded from WA to SA. Womersley (2003) says a record from the north coast of Tas. is "possible".

Appendix 1 cont.

Collecting no.	Species	Family	Depth	Collectors	Habitat and remarks
KA 00550a, b	*Laurencia tasmanica* Hooker f. & Harvey (1849)	Rhodomelaceae	1–3 m	C. Sanderson & J. Kaiser	Thalli growing on rock between the wharf and the jetty in Freestone Cove. First named from Georgetown, the species now recorded from WA to Vic. as well as Tas.
KA 00577	*Laurencia tasmanica* Hooker f. & Harvey (1849)	Rhodomelaceae	1–3 m	J. Kaiser & C. Sanderson	Thalli growing on rock between the wharf and the jetty in Freestone Cove. First named from Georgetown, the species now recorded from WA to Vic. as well as Tas.
KA 00496	*Hemineura frondosa* (Hooker f. & Harvey) Harvey (1849)	Delesseriaceae	5–10 m	M. Tatsumi & E. Kennedy	A tetrasporangial thallus growing on an outer wharf piling. Very common from WA to Vic. and around Tas., also NZ. The first collections were from Georgetown.
KA 00543a–c	*Hemineura frondosa* (Hooker f. & Harvey) Harvey (1849)	Delesseriaceae	1–3 m	C. Sanderson & J. Kaiser	Tetrasporangial thalli on stalks of the seagrass *Zostera muelleri* on rock between the wharf and the jetty in Freestone Cove. Very common from WA to Vic. and around Tas., also NZ. The first collections were from Georgetown. **PLATE 9D**
KA 00574a, b	*Hemineura frondosa* (Hooker f. & Harvey) Harvey (1849)	Delesseriaceae	1–3 m	J. Kaiser & C. Sanderson	A cystocarpic (a) and a sterile (b) thallus on a rock between the wharf and the jetty in Freestone Cove. Very common from WA to Vic. and around Tas., also NZ. The first collections were from Georgetown; numerous at Spring Bay.
KA 00544	*Acrosorium ciliolatum* (Harvey) Kylin (1924)	Delesseriaceae	1–3 m	C. Sanderson & J. Kaiser	Thallus in algal turf on a rock between the wharf and the jetty in Freestone Cove. Originally described from King George Sound, this species is now recorded from most world oceans.
KA 00464a, b	*Phycodrys australasica* A.J.K.Millar (1990)	Delesseriaceae	1–3 m	S. Brooks	Tetrasporangial thalli among low turf algae on a wharf piling. Only recently described from Port Phillip Bay, the species now known from WA to NSW, around Tas. and north to Lord Howe and Norfolk Islands.
KA 00464.1	*Phycodrys australasica* A.J.K.Millar (1990)	Delesseriaceae	1–3 m	S. Brooks	A spermatangial (male) thallus among low turf algae on a wharf piling. This appears to be the first record of a male plant for this species. **PLATE 8E**
KA 00480a–d	*Neoharaldiophyllum nottii* (R.E.Norris & M.J.Wynne) C.Kang & M.S.Kim (2017)	Delesseriaceae	3–6 m	S. Brooks	Sterile (a) and tetrasporangial (b–d) thalli on outer pilings of the wharf. Although rarely reported, it was one of the commonest red algae on the pilings.
KA 00497; KA 00512	*Neoharaldiophyllum nottii* (R.E.Norris & M.J.Wynne) C.Kang & M.S.Kim (2017)	Delesseriaceae	6–10 m	M. Tatsumi & E. Kennedy	Tetrasporangial thalli growing on an outer wharf piling. A possible adventive as its prior records were British Columbia and Washington State as well as Vic. and Tas.; it is rarely reported but was one of the commonest red algae on the pilings. **PLATE 9E**

Appendix 1 cont.

Collecting no.	Species	Family	Depth	Collectors	Habitat and remarks
KA 00545	*Neoharaldiophyllum nottii* (R.E.Norris & M.J.Wynne) C.Kang & M.S.Kim (2017)	Delesseriaceae	1–3 m	C. Sanderson & J. Kaiser	Tetrasporagial thallus growing on a rock between the wharf and the jetty in Freestone Cove. A possible adventive as its prior records were British Columbia and Washington State as well as Vic. and Tas.; it is rarely reported but was one of the commonest red algae on the pilings.
KA 00510; slides KA 00510a, b	*Heterosiphonia gunniana* (Harvey) Reinbold (1899)	Delesseriaceae	5–10 m	M. Tatsumi & E. Kennedy	Tetrasporangial thallus growing on an outer wharf piling. Recorded from across southern Australia and around Tas.
KA 00575a, b	*Heterosiphonia gunniana* (Harvey) Reinbold (1899)	Delesseriaceae	1–4 m	J. Kaiser & C. Sanderson	Thalli from rocks between the wharf and the jetty in Freestone Cove. Recorded from across southern Australia and around Tas. **PLATE 8F**
KA 00511, slides a and b	*Heterosiphonia australis* (J.Agardh) De Toni (1903)	Delesseriaceae	5–10 m	M. Tatsumi & E. Kennedy	Tetrasporangial thalli among low algal turfs on an outer piling of the wharf. Recorded from WA to NSW and eastern Tas.; also Lord Howe and Norfolk Islands. Port Jackson is the type locality.
KA 00461a–l, slide KA 00461a	*Dasya villosa* Harvey (1844)	Delesseriaceae	1–3 m	S. Brooks	Tetrasporangial (a, b), sterile (c–i) and cystocarpic (j–l) thalli on pilings of the wharf. This is the dominant red alga on the wharf pilings. First named from Georgetown, it ranges from WA to Vic. and around Tas. **PLATE 8D**
KA 00479a–e	*Dasya villosa* Harvey (1844)	Delesseriaceae	3–6 m	S. Brooks	Tetrasporangial (a–c) and spermatangial (d, e) thalli on an outer piling of the wharf. This is the dominant red alga on the wharf pilings. First named from Georgetown, it ranges from WA to Vic. and around Tas.
KA 00509	*Dasya villosa* Harvey (1844)	Delesseriaceae	5–10 m	S. Brooks	Sterile thallus on an outer piling of the wharf. This is the dominant red alga on the wharf pilings and rocks.
KA 00546	*Dasya villosa* Harvey (1844)	Delesseriaceae	1–3 m	C. Sanderson & J. Kaiser	Sterile thallus growing on a nearshore rock between the wharf and the jetty in Freestone Cove. This is the dominant red alga on the wharf pilings and rocks. First named from Georgetown, it ranges from WA to Vic. and around Tas.
KA 00573a–c	*Dasya villosa* Harvey (1844)	Delesseriaceae	1–4 m	J. Kaiser & C. Sanderson	Sterile thalli growing on a nearshore rock between the wharf and the jetty in Freestone Cove. This is the dominant red alga on the wharf pilings and rocks. First named from Georgetown, it ranges from WA to Vic. and around Tas.
KA 00498; slice KA 00498a	*Dasya divergens* Parsons & Womersley (1998)	Delesseriaceae	6–9 m	M. Tatsumi & E. Kennedy	Sterile thallus growing on an outer piling of the wharf. The type locality is Robe, SA, the species recorded from WA to Vic. First record for Tas.
KA 00462	*Dasya crescens* Parsons & Womersley (1998)	Delesseriaceae	1–3 m	S. Brooks	Juvenile thallus epiphytic on male *Neoharaldiophyllum nottii* on a piling of the wharf. The type locality is northern Tas., but no records further south have been made until now.

Appendix 1 cont.

Collecting no.	Species	Family	Depth	Collectors	Habitat and remarks
KA 00462 slides a and b	*Dasya crescens* Parsons & Womersley (1998)	Delesseriaceae	1–3 m	S. Brooks	Sterile (00462a) and tetrasporangial (00462b) slide mounts of KA 00464. The type locality is northern Tas., but no records further south have been made until now.
KA 00579	*Dasya* sp.	Delesseriaceae	1–4 m	J. Kaiser & C. Sanderson	Lax, sterile fronds probably from a shoreward wharf piling. Material is not a match for any of the *Dasya* species in Womersley (1998).
KA 00515a, b	*Halophila australis* Doty & B.C.Stone (1966)	Hydrocharitaceae	1–3 m	C. Sanderson & J. Kaiser	Seagrasses anchored in sand patches among nearshore rocks between the jetty and the wharf. Generally only the blades of this seagrass host epiphytes; the type locality is Queenscliff, the species ranges from WA to NSW.
KA 00557	*Halophila australis* Doty & B.C.Stone (1966)	Hydrocharitaceae	1–3 m	J. Kaiser & C. Sanderson	Seagrasses anchored in sand patches among nearshore rocks between the jetty and the wharf. Generally only the blades of this sea-grass host epiphytes; the type locality is Queenscliff, the species ranges from WA to NSW. **PLATE 11A**
KA 00556a, b	*Zostera muelleri* Irmisch ex Ascherson (1867)	Zosteraceae	1–3 m	J. Kaiser & C. Sanderson	Seagrasses growing on nearshore rock between the jetty and the wharf. The woody stalks of this seagrass host numerous algal and invertebrate epiphytes. Ranges from SA to NSW and to NZ. **PLATE 11B**
KA 00516a, b	*Zostera muelleri* Irmisch ex Ascherson (1867)	Zosteraceae	1–3 m	C. Sanderson & J. Kaiser	Seagrasses growing on nearshore rock between the jetty and the wharf. The woody stalks of this seagrass host numerous algal and invertebrate epiphytes. Ranges from SA to NSW and to NZ.

[1] Collected 19 November 2019. Specimens all determined by G.T. Kraft.

APPENDIX 2 — Specimens collected[1] from Louisville Point, west coast of Spring Bay, Tasmania, Australia, 42°32'27"S; 147°54'52"E

Collecting no.	Species	Family	Depth	Collectors	Habitat and remarks
KA 00441	*Ulva australis* Areschoug (1854)	Ulvaceae	0.20–0.40 m	G.T. Kraft	Thalli growing in rockpools and in a band paralleling shore on a 0.50 m low tide just north of the Eastcoaster Resort. The dominant macrophyte.
KA 00442	*Ulva australis* Areschoug (1854)	Ulvaceae	0.20–0.40 m	G.T. Kraft	Thalli growing in rockpools and in a band paralleling shore on a 0.50 m low tide just north of the Eastcoaster Resort. The dominant macrophyte.
KA 00443	*Cladophora rhizoclonioidea* Hoek & Womersley (1984)	Cladophoraceae	0.20 m	G.T. Kraft	A loose ropey skein growing on the floor of a surge-exposed rockpool entangled with thalli of *Asparagopis armata*. This is the first record of this rarely reported, recently described species south of its type locality, Georgetown. Otherwise only known from one place in SA. **PLATE 2E**
KA 00444	*Chaetomorpha billardieri* Kützing (1847)	Cladophoraceae	0.15–0.30 m	G.T. Kraft	A few solo strands entangled with various macrophytes in surge-exposed rockpools. The commonest unbranched green in Tas. It occurs across southern Australia.
KA 00445	*Zonaria turneriana* J.Agardh (1870)	Dictyotaceae	0.20 m	G.T. Kraft	A single large, heavily fruiting thallus free-floating over the base of a surge-exposed rockpool. A common species from across southern Australia and around Tasmania.
KA 00446	*Sargassum fallax* Sonder (1845)	Sargassaceae	0.20 m	G.T. Kraft	A single mature but non-reproductive thallus on rock, the distal frond just submerged in a surge-exposed rockpool. One of the most common *Sargassum* species in the southern half of Australia.
KA 00447	*Sargassum fallax* Sonder (1845)	Sargassaceae	0.20 m	G.T. Kraft	A single juvenile thallus on rock in a surge-exposed rockpool. One of the most common *Sargassum* species in the southern half of Australia.
KA 00448	*Asparagopsis armata* Harvey (1855)	Bonnemaisoniaceae	0.15–0.30 m	G.T. Kraft	A few non-reproductive thalli caught up in a skein of *Cladophora rhizoclonioidea* growing in a surge-exposed rockpool. A common species all along southern coasts. It has an alternative stage that looks very different.
KA 00449 a,b	*Corallina officinalis* Linnaeus (1758)	Corallinaceae	0.06–0.10 m	G.T. Kraft	Thalli forming dense rounded heads on the floor of a shallow surge-exposed rockpool. Common in intertidal habitats not just in Australia but virtually worldwide. **PLATE 7C**
KA 00450 a,b	*Centroceras clavulatum* (C.Agardh) Montagne (1846)	Ceramiaceae	0.08–0.12 m	G.T. Kraft	Thalli growing in dense tufts and clumps on the lower vertical sides of a shallow surge-exposed rockpool. A species common in Australia and around the world.
KA 00451	*Lophothamnion hirtum* (Hooker f. & Harvey) Womersley (1998)	Wrangeliaceae	0.15–0.20 m	G.T. Kraft	Thalli fairly numerous, growing on vertical rock above the floor of a shallow surge-exposed rockpool. This is a species recorded from S.E. Australia, the north and south of NZ, and various subantarctic islands. **PLATE 9C**
KA 00452 a,b	*Polysiphonia scopulorum* Harvey (1855)	Rhodomelaceae	0.10–0.18 m	G.T. Kraft	Low dense clumps of intertwined thalli growing on vertical rock above the floor of a shallow surge-exposed rockpool. The type locality of this species is Rottnest Island, but its present distribution is all over Europe, the Mediterranean, east and west Atlantic coasts and the Caribbean, Brazil, Pacific North America, Egypt and South Africa, China and the Philippines, Pacific tropical islands and around Australia and NZ. Womersley (2003) speculates that it might be a long-standing Australian adventive.
KA 00453	*Laurencia botryoides* (C.Agardh) Gaillon (1828)	Rhodomelaceae	0.15 m	G.T. Kraft	A single thallus on the floor of a shallow surge-exposed rockpool. Occurs from SA to Vic. and around Tas. **PLATE 9F**

[1] Collected 5 December 2019. Specimens all determined by G.T. Kraft.

SOLVING THE MYSTERY OF THE "HOBART GOLD" – THE IDENTITY AND REDESCRIPTION OF THREE TASMANIAN LEAF BEETLE SPECIES OF THE GENUS *PAROPSISTERNA* MOTSCHULSKY, 1860 (COLEOPTERA: CHRYSOMELIDAE: CHRYSOMELINAE)

by David W. de Little, Chris A.M. Reid and Martin Lagerwey

(with six plates)

de Little, D.W., Reid, C.A.M. & Lagerwey, M. 2022 (i:xii): Solving the mystery of the "Hobart Gold" – the identity and redescription of three Tasmanian leaf beetle species of the genus *Paropsisterna* Motschulsky, 1860 (Coleoptera: Chrysomelidae: Chrysomelinae). *Papers and Proceedings of the Royal Society of Tasmania* 156: 31–42. ISSN 0080-4703 Tasmanian Museum and Art Gallery, GPO Box 1164, Hobart, Tasmania 7001, Australia (D de L*); Australian Museum, 1 William Street, Sydney, NSW 2010, Australia (CAMR); 20 View Street, Croydon, Victoria 3136, Australia (ML). *Author for correspondence. Email: dcdelittle@bigpond.com

Three Tasmanian species of leaf beetles, belonging to the *nobilitata* species-group of *Paropsisterna* Motschulsky,1860, are identified and redescribed: *P. hectica* (Boisduval, 1835); *P. simsoni* (Blackburn, 1899); and *P. vittata* (Blackburn, 1899). *Paropsisterna hectica* is a senior synonym of *P. aurea* (Blackburn, 1899) (new synonym). A neotype is designated for *P. hectica*, and lectotypes designated for *P. aurea*, *P. simsoni* and *P. vittata*. *Paropsisterna vittata,* described from alpine Victoria, is identified in Tasmania for the first time, and its similarity to *P. selmani* Reid & de Little, 2013 noted. The brilliant living colours of the adults are illustrated. *Paropsisterna simsoni* (the "Hobart Gold") is shown to be a valid species and not an immature form of *P. aurea* as previously suggested.

Key Words: taxonomy, forestry, Tasmania, Australia, paropsine.

INTRODUCTION

The genus *Paropsisterna* Motschulsky, 1860, as re-defined by Reid (2006) and containing some 120 species, is distributed throughout Australia with some species also in New Guinea and Timor (Mohamedsaid 2009). De Little (2011) listed 17 identified species occurring in Tasmania and a further four unidentified species.

Motschulsky's division of *Paropsis* Olivier, 1807 into several genera was ignored by the major reviser of the Australian paropsines, Thomas Blackburn, who treated them all as *Paropsis* species. Blackburn (1899) recognised a group of approximately 50 species which are brightly coloured in life, but lose colouration after death, fading to a uniform dull light brown, as a sub-group within *Paropsis* for which Weise (1901) proposed the generic name *Chrysophtharta*. Reid (2006) synonymised *Chrysophtharta* with *Paropsisterna* due to the lack of consistent diagnostic characters separating them. Most species formerly placed in *Chrysophtharta* are provisionally referred to as the "*nobilitata* species-group of *Paropsisterna*" (Reid & de Little 2013). The taxonomy of this group is very confused due to colour pattern loss after death and the dearth of consistent morphological characters; however, sculpture of the male genitalia is usually diagnostic (Reid & de Little 2013, Nahrung *et al.* 2020).

Paropsisterna is of economic significance due to several species being recognised as significant pests of *Eucalyptus* species by the forestry industry, both in Australia (de Little 1989) and overseas, where four species have become introduced pests (Simmul & de Little 1999, Nahrung *et al.* 2020). Notable among these is *Paropsisterna selmani* Reid & de Little 2013 introduced into Ireland, where it attacks eucalypts cultivated for the floristry industry (Reid & de Little 2013, Fanning & Baars 2014). This species, formerly rare in its native Tasmania, is now recognised as a significant pest of the introduced *Eucalyptus nitens*, a species widely planted in Tasmania by the forestry industry (Elek & Patel 2016).

De Little (1979), in his studies of the ecology of Tasmanian eucalypt defoliating paropsines, identified two brilliantly coloured species as *Paropsisterna aurea* (Blackburn, 1899) and *P. simsoni* (Blackburn, 1899) using Blackburn's (1899) key and descriptions. The elytra of these species when alive have extremely variable but diagnostic colouration consisting of brilliantly shining golden, green, pink or red figuration which fades on death. Blackburn's hand-written labels attached to the series of five *P. simsoni* syntypes (NHML and SAM, abbreviations below) refer to the "Hob.[art] gold immature". British chrysomeline taxonomist Brian Selman, who examined these syntypes, suggested that since they were all labelled "immature" and therefore paler than, but otherwise superficially similar to, Blackburn's *P. aurea* syntypes, *P. simsoni* was a junior synonym of *P. aurea* (Selman pers. comm. to de Little 1980).

We have re-examined Blackburn's syntypes and additional material in SAM, AMS and TMAG (abbreviations below). *Paropsisterna aurea*, described from Tasmania, is here shown to be conspecific with the species currently identified on the mainland as *P. hectica* (Boisduval, 1835). The species incorrectly identified by de Little (1979) as *P. simsoni* is here shown to be *P. vittata* (Blackburn, 1899), originally described from alpine Victoria. Murphy (2006) incorrectly identified Tasmanian *P. vittata* as *P. hectica*. *Paropsisterna simsoni* (the "Hobart Gold") is found to be the previously

unidentified species provisionally labelled "*Chrysophtharta* sp. Ch8" by de Little (1979). The three hitherto confused valid species occurring in Tasmania (*P. hectica*, *P. simsoni* and *P. vittata*) are here redescribed and appropriate type material designated. Examination of *P. vittata* shows the species to be closely allied with *P. selmani*.

Lectotypes have been designated when required, according to the rules of the ICZN (http://iczn.org/ articles 73 and 74) to fix the taxonomy and avoid any ambiguity in interpretation of these similar species.

MATERIAL EXAMINED

Abbreviations:
AMS: Australian Museum, Sydney, Australia
ANIC: Australian National Insect Collection, Canberra, Australia
NHML: Natural History Museum, London, United Kingdom
SAM: South Australian Museum, Adelaide, Australia
TMAG: Tasmanian Museum and Art Gallery, Hobart, Australia

TAXONOMY

Paropsisterna Motschulsky, 1860

Type species: *Notoclea sexpustulata* Marsham, 1808, by original designation.

A key identifying the genus *Paropsisterna* in Australia, revised generic description and full generic synonymy are provided by Reid (2006). The species re-described below are typical members of the *Paropsisterna nobilitata* species-group.

Paropsisterna nobilitata species-group

This group, consisting of most of the species formerly placed in *Chrysophtharta* (Weise 1901), is distinguished within *Paropsisterna* by: mesoventral process excavate anteriorly and posteriorly; dorsal colour in life often bright, shining or metallic but fading to brown after death; first instar larvae without long setae.

***Paropsisterna hectica* (Boisduval, 1835)**

(plates 1A, 1B, 2A, 2B, 2C, 3)

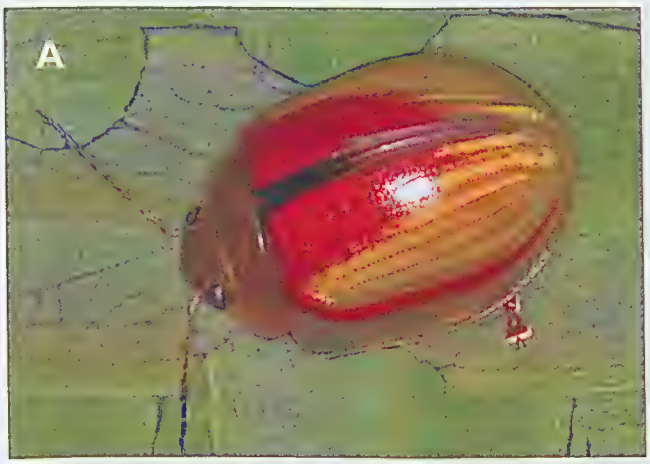
Paropsis hectica: Boisduval 1835: 569 (type locality: New Holland)
Chrysophtharta hectica: Weise 1916: 164
Paropsisterna hectica: Reid 2006: 116
Paropsis aurea: Blackburn 1899: 497 (type locality: Hobart, Tasmania); new synonym

Material examined

Types. Neotype of *Paropsis hectica* (this designation): ♀/TMAG F122796; Hobart, Mt. Nelson. 42.979S x 147.329E. Beating coll. D. W. de Little 14 Jan 2022/Neotype *Paropsis hectica* Boisduval des. de Little, Reid & Lagerwey 2022 (TMAG). Lectotype of *P. aurea* (this designation): ♂/Type [printed circular NHML label]/6126 Hob.[art] T. [Blackburn's handwriting]/Blackburn coll. 1910–236/Lectotype *Paropsis aurea* (Blackburn) des. de Little, Reid & Lagerwey 2022 (NHML). Paralectotypes (4): ♀/Hob.[art]/*Paropsis aurea* Blackb./17424/Paralectotype *Paropsis aurea* (Blackburn) des. de Little, Reid & Lagerwey 2022 (SAM); ♂, 2♀/Hob.[art]/*Paropsis aurea* Blackb./Paralectotype *Paropsis aurea* (Blackburn) des. de Little, Reid & Lagerwey 2022 (SAM).

Other material. Australia: 1/*Paropsis aurea* Blackb [Blackburn's handwriting]/(AMS); **Australian Capital Territory**: 1/Mt Gingera *Eucalyptus pauciflora* 23.i.1985 C Reid/ (AMS); 2/summit Mt Ginini, Brindabella Ra, c1750m, 35.31S 148.46E, Snowgum Woodland, 17.xii.2006, C Reid/(AMS); **New South Wales**: 1/NSW/(AMS); 1/ '4617 A7–8' [Blackburn's handwriting?]/(AMS); 3/Dead Horse Gap, Kosciusko NP, 36:31S 148:15E 1570m, 27.i–4.ii.2014 U Lallu/(AMS); 1/Kosciusco, Helms 1893/(AMS); 1♂/Kosciusko NP, N slopes Mt Stilwell, 1800–1900 m 36:28:05S 148:19:45E Snowgum Woodland, Snowgum 5–6.i.2006 C Reid/(AMS); 3/Kosciusko NP, Mt Stilwell Track, 36:26S 148:19E, 1865m, on Snowgum, 24–28. xii.2017 C Reid/(AMS); 1/Thredbo YHA, Kosciusko NP, 36:30S 148:18E 1410m 27.i–4.ii.2014 U Lallu/(AMS); ♂/TMAG F97719/Crackenback, Alpine Way, NSW; -36.447, 148.496; Beating *E[ucalyptus] pauciflora*; Coll. M. Lagerwey 05 Mar 2018/ (TMAG); 2♂/TMAG F40342; F97727, Crackenback, Alpine Way, NSW, -36.447, 148.496, Beating *E[ucalyptus] pauciflora*, Coll. M. Lagerwey 05 Mar 2018/(TMAG); ♀/Mt Kosciusko Holms 1893/metall.colour as *citrina*/*hectica*, Boisd./(SAM); **Tasmania**: 2/Tasmania [Master's handwriting]/(AMS); 1/Blackwood Ck, 12.i.1994 LD Buddle/(AMS); 4/ Lake St Clair 13.i.1937 G & C Davis/(AMS); 1/ Parratah, Blackwood/(AMS); 2/5k S Strahan airfield, 42:10:58S 145:16:45E, *Euc. nitida* (mallee form) in open heath, 16m, 8–13.xi.2010 C Reid/(AMS); 2/Wadamanna 11.i.1994 LD Buddle/(AMS); 4♂/ -42.0517, 146.3354, GDA94, South of Kenneth Lagoon, "Skullbone Plains", Tasmania, 27 Feb 2012, [col.] D. W. de Little/TMAG F6130, F6129, F6132, F6131, *Paropsisterna hectica* Det. D. de Little, 2020/(TMAG); ♂, ♀/ -40.0612, 148.0886, GDA94, Leventhorpe Gully, Flinders Island, Tasmania, 23 Mar 2014, [col.] D.W. de Little/TMAG F6719, F6724, *Paropsisterna hectica* Det. D. de Little 2020/(TMAG); ♀/Hobart 91–88/*Chrysophtharta aurea* Blkb./Exchange ex

PLATE 1 (opposite) — Habitus images of adult beetles, dorsal view. **A** and **B**. *Paropsisterna hectica* (Boisduval, 1835). **C** and **D**. *P. simsoni* (Blackburn, 1899). **E** and **F**: *P. vittata* (Blackburn, 1899). **G** and **H**. *P. selmani* (Reid & de Little, 2013).


A

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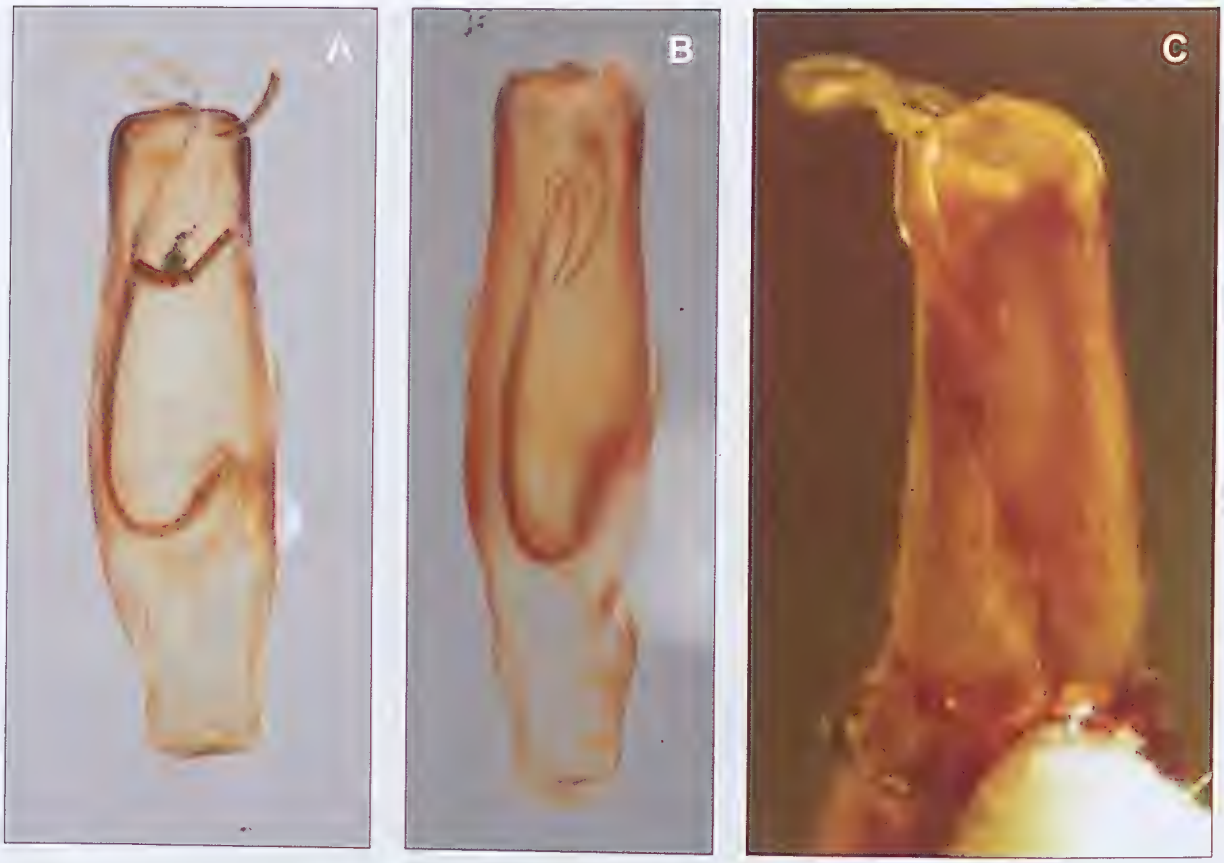

PLATE 2 — Aedeagi of *Paropsistema* species. **A**. *P. hectica*, New South Wales (TMAG F97719). **B**. *P. hectica*, Tasmania (TMAG F6130). **C**. *P. aurea* Lectotype, Tasmania (NHML).

BM(NH)/ (ANIC); ♂/Maggs Mt. Hut, 11.xi.1975, R. H. Green on eucalypt ex Launceston Museum/*C. aurea* det C. R.[eid] 1985/ (ANIC); ♀/TAS, "Surrey Hills", Bunkers Road, -41.37, 145.68, 27 Nov 1974, [col.] D.W. de Little/ TMAG F14997, *Paropsisterna hectica*, Det. D. de Little, 2015/*Eucalyptus nitida*/(TMAG); **Victoria**: 3/ 2k NW Anglesea 38:23S 144:08E *Euc pauciflora* 35m i.2015 M Lagerway[sic]/(AMS); 3/Mt Buffalo, 4400ft, 19.xii.1933 A Musgrave/(AMS); 1/Mt Buffalo NP, Kowan Plains nr Mt Buffalo Lodge, ex *E pauciflora*, 12.i.2001 D Dobrosak/ (AMS); 2/Mt Buffalo NP, path to Dixons Falls, c1475m, 36:46:02S 146:47:21E, *Euc pauciflora*, 15.xi.2010 C Reid/ (AMS); 1/Mt Buffalo NP, path to Dixons Falls, c1475m, 36:46:28S 146:47:40E, *Euc pauciflora*, 28.xi–2.xii.2011 C Reid/(AMS); 3/Mt St Bernard Hospice, 19.xii.1933 A Musgrave/(AMS); ♀/TMAG F40343 VIC. Anglesea, Bald Hills Rd -38.378, 148.496, Reared D. de Little, 24 Jan 2019/*Paropsisterna hectica* (Boisduval, 1835), Det. D. de Little, 2019/(TMAG).

Diagnosis. Live adult with disc of elytra uniformly bright golden yellow (pl. 1B) or pale green sometimes with scarlet colour at base and extending variably to apex (pl. 1A); dead and live adults with black pigmentation at base of head medially drawn backwards in V-shape; pronotal anterior angles rounded, discal puncturation much finer than marginal puncturation; elytral seriate puncturation fine and regular, interstitial puncturation finer; ventrites of dead specimens variably pale brown to black (pl. 3); femora sometimes with dark mark distally; middle third of penis broadest in ventral view, narrowing smoothly to a truncate apex with small mucron apex, with a diagnostic everted loosely coiled and apically thickened flagellum (pl. 2A, B, C).

Description. Adult. Length: ♂, 7–8 mm ♀, 8.5–9.5 mm; body broadly ovate (length to width ratio 1.3) and convex (length to height ratio 2.3), with highest point at about half body length; head slightly wider than half pronotal width; elytra at anterior angles 1.3x pronotal width. Colour pattern of mature live beetle translucent pale brown head black at base with pigmentation drawn back centrally in a shallow V shape towards base, eyes black, antennomeres 7–11 dark brown, pronotum pale brown, legs pale brown, black patch at distal end of femur, scutellum dark brown, elytral suture black for one-third of its length to nearly entire length from base to apex, elytral disc of mature adults with sulcate appearance, the sulcations corresponding to rows of seriate puncturation, variable bright pale green, yellow or rosy gold, sometimes with bright vermilion colour extending variably from base of elytra towards apex and obliterating sulcate appearance, being more extensive adjacent to elytral suture and sometimes discal margin, elytral disc of teneral adults clear green-yellow-gold; elytral margins translucent. Colour of dead mature beetle entirely yellow-brown except base of head black, thoracic and abdominal ventrites variably brown to black. Pubescence: head with depressed areas adjacent to eyes with erect setae,

PLATE 3 — Ventral colouration of *Paropsisterna hectica* showing variation in specimens collected from neotype locality, Mt Nelson, Hobart, Tasmania.

two long setae projecting anteriorly from sides of apical margin of clypeus; rest of head, all of pronotum (including hypomera) and elytra (including epipleura) glabrous; prosternum glabrous except setose anterior margin and apex of prosternal process; mesepimera and mesoventrite glabrous except process; metanepisterna, metaventrite glabrous; abdominal ventrites glabrous except lateral margins and apex ventrite V densely setose; antennomeres 4–11 with smooth impunctate midline and raised setae either side of this; femora almost glabrous; tibiae setose, densely towards apices; ♂ with ovate pads of spathulate setae on pro-, and meso- first-tarsomeres.

Head: eyes small, separated by about 4x greatest widths; frontoclypeus irregularly punctured, with mixed large (slightly larger than eye facets) and small (slightly smaller than eye facets) punctures, often coalescent in small pits, densely and finely punctured in depressed areas adjacent to eyes, more evenly sized and not coalescing at base of head (in black area); interspaces finely microreticulate; antennae about half body length, all antennomeres elongate, 2 shortest, 11 longest; 1 and 3 almost as long as 11, 4–11 distinctly flattened, 5–10 slightly asymmetric; labrum microreticulate, finely and sparsely punctured, apex shallowly concave; securiform apical maxillary palpomere broader in ♂, with sharper lateral angles.

Thorax: pronotum strongly transverse, width c. 2.3x length, posterior angles broadly rounded, anterior angles strongly produced and bluntly rounded; pronotal margins entirely finely beaded; disc of pronotum (area behind vertex) punctured at head but punctures and interspaces larger, punctures increasing in size and conflation towards sides of pronotum which are rugose with irregular slightly ridged intervals; pronotal surface shining with scattered micropunctures; prosternum with elevated smooth ridge along midline commencing at anterior margin, posteriorly bifurcating to follow lateral margins of process (middle of process depressed); prosternal process elongate spatulate, reaching well beyond posterior margins of procoxae; scutellum elongate semi-ovate, strongly micropunctured; elytra broadest at about middle, but with laterally prominent obtuse anterior angles (about 100°); humeri prominent, at about 3/5 width from suture to lateral margin; scutellary striole strongly punctured, 9 distinct striae, strial punctures slightly larger than those on pronotal disc, striolar and strial punctures linearly and regularly placed; striae 4 and 5 anastomosed well before apex, striae 2, 3 and 6–8 anastomosing closer to apex, then merging with striae 1 and 9 in large irregular punctures at elytral apex; intervals 1–9 and strip outside stria 9 with scattered fine punctures, similar to pronotal disc; slightly reflexed outer margins of elytra with broad strongly punctuate area, punctures more evenly spread and larger than on pronotal disc; mesoventrite deeply hollowed anteriorly to accommodate prosternal process, small tubercle either side of hollow; mesoventrite process strongly elevated, anterior face deeply concave and posterior face (apex) deeply concave; metaventrite smooth except finely wrinkled and punctuate in lateral angles, process flat or slightly elevated; inner margins

of protibiae slightly concave before apex; apical third of meso- and metatibiae with dorsal seta-fringed excavation to accommodate tarsi; male pro- and meso- first tarsomeres ovate, female elongate-triangular; claws with acute tooth on middle of ventral surface.

Abdomen: ventrites I–IV shining but finely microreticulate, close and finely punctured at base, wrinkled at sides, with sparse fine punctures elsewhere; ventrite V as I–IV, but without lateral wrinkles and more closely punctured, with subapical transverse setose groove in both sexes; apex of male ventrite V truncate with slight median convexity, apex of female broadly convex; middle third of penis expanded in ventral view, apex squarish with rounded corners and central bluntly pointed triangular tip with a diagnostic everted and loosely coiled, apically thickened flagellum.

Larva. Four larval instars (L1–4). Head capsule widths: L1: 0.9 mm; L2: 1.2 mm; L3: 1.5 mm; L4: 2.0 mm. L4 maximum length 15 mm. L1–4 with smooth head capsule (without papillae), relatively long setae, up to 2x length of tarsungulus in L1, and narrow abdomen tapering towards apex. Larval instars becoming progressively paler to yellowish green L4 but retaining black body tubercles.

Egg. Elongate-oval, length 2.8 mm, width 1.1 mm, chorion tuberculate, mauve-brown. Deposited singly or in rows end-to-end on foliage.

Notes. Boisduval's (1835) *Paropsis hectica* type is lost and his brief description, "pale yellow, smooth, elytra very feebly marked with punctured striations; underside the same colour" (authors' translation), although fitting this species, is not diagnostic. The description may have referred to a female, this sex often having less ventral black pigmentation than males. Mainland specimens generally have darker ventral colouration than Tasmanian specimens. The specimen would have been long dead and therefore straw-coloured, having lost its striking live colouration. The collection data are "New Holland, collection of M. Dejean". The Dumont d'Urville *Astrolabe* expedition 1826–9, on which this species was collected, made landfall at several Australian locations, *viz*: King George's Sound, Western Australia, Westernport, Victoria; Jervis Bay, NSW; Port Jackson, NSW; and Hobart, Tasmania (Musgrave 1932). Of these locations, only Hobart, Tasmania, falls within today's known distribution range of *P. hectica*/*P.aurea*, and it is also the only known location where females have a pale venter (pl. 3). It is uncertain whether the locality designation "New Holland" was meant to include Tasmania or not; Boisduval (1835) occasionally specifying "Tasmanie" or Van Diemen's Land as localities for new species he described; however, localities of all "Astrolabe" specimens described from Dejean's collection are simply designated "New Holland".

Chapuis (1877) provided a more detailed description of *P. hectica* giving Tasmania and Victoria as occurrence localities. He also described the ventral colour as black with abdomen and legs red-brown, apex of femora marked with black but sometimes (mainly the female) with the legs yellowish red-brown.

Blackburn (1899) commented on this species based on Chapuis' (1877) description, stating that: "the type (assuming Dr. Chapuis' identification to be correct, I have an example named by that learned author) occurs in New South Wales, but in my experience is rare. Its special characteristics consist in the under surface, legs and antennae being entirely of pale brown colour" (Blackburn 1899, p. 499). Blackburn noted that the species was highly variable with "races" in New South Wales (rare), alpine Victoria and South Australia. A Tasmanian form was described as a separate species, *P. aurea* (Blackburn 1899), based on its brilliant golden yellow gloss when live and the strong black pigmentation of the elytral suture.

Examination of living and dead specimens from New South Wales and Victoria (generally referred to "*hectica*") and Tasmania (generally referred to "*aurea*"), including Blackburn's type material, together with dissection and examination of the penis, and the rearing of immature stages of both Tasmanian and mainland Australian forms, has led to the conclusion that there is only one species. The colour of live adults is quite variable, ranging from the brilliant yellow gloss of "*aurea*" to the elytral disc being suffused with a bright vermillion red during diapause, that disappears from the elytral apex towards the base and suture to reveal a brilliant yellow, lime green or rosy gloss as the beetles emerge in spring and become sexually active. Ventral black pigmentation is variable (pl. 3) with males generally having more than females, some of which are entirely pale.

We have selected a female with pale venter collected near Hobart, Tasmania, as the neotype of *Paropsis hectica*, in the belief that despite Blackburn's (1899) statement to the contrary, and the original location being given as simply "New Holland", the original specimen described by Boisduval (1835) was in all probability collected in the vicinity of Hobart between 18 December 1827 and 5 January 1828, while the *Astrolabe* was in dock there (Musgrave 1932).

The larvae are quite distinct from larvae of other related ("*nobilitata* group") species, being more elongate (lanceolate) in form, having a smooth surfaced head, and with well-defined sclerites bearing relatively long setae.

Paropsisterna hectica is a common species throughout Tasmania where it is often found on *Eucalyptus amygdalina, E. pulchella, E. nitida, E. coccifera* and *E. pauciflora*. On mainland Australia it is usually associated with *E. pauciflora*.

Paropsisterna simsoni (Blackburn, 1899)

(plates 1C, 1D, 4A, 4B, 5A, 5B, 5C)

Paropsis simsoni: Blackburn 1899: 500
Chrysophtharta simsoni: Weise 1916: 165
Paropsisterna simsoni: Reid 2006: 116

Material examined

Types. Lectotype (this designation). ♂/6452 Hobart, T.[asmania] [Blackburn's handwriting]/ ? Hob.[art] gold immature/*Paropsis simsoni* Blackb./Blackburn coll. 1910_236/Type [printed circular NHML label]/Lectotype *Paropsis simsoni* Blackburn, 1899, des. de Little, Reid &

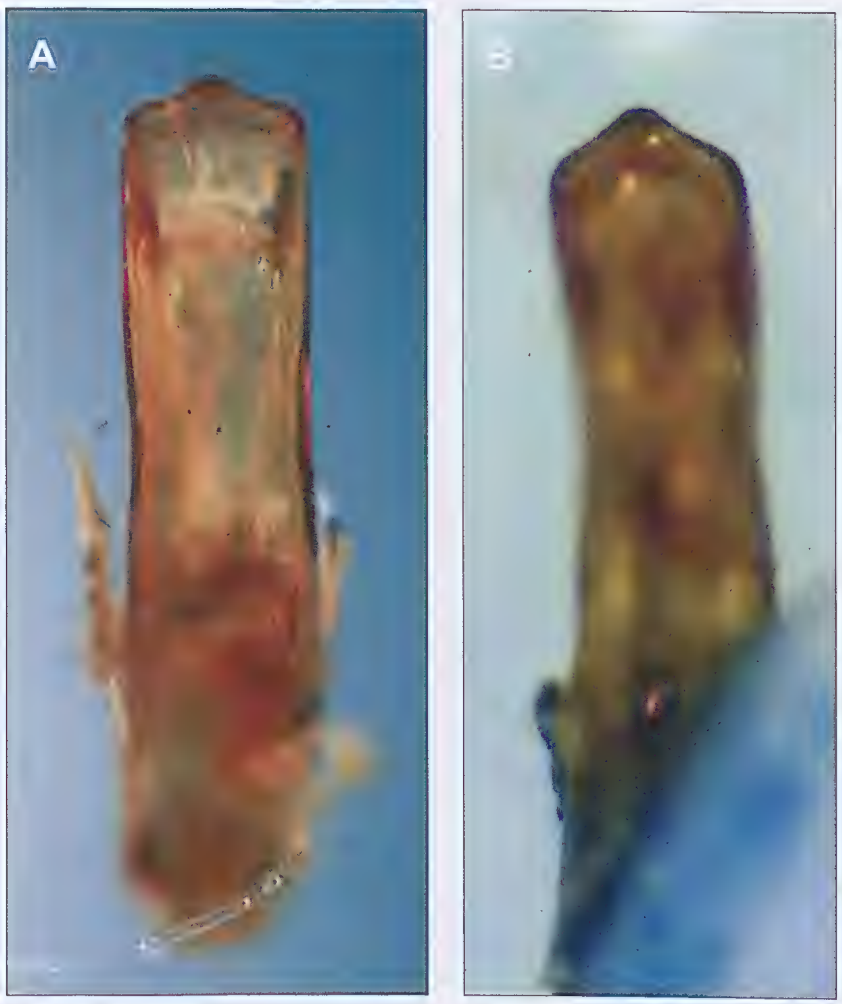

PLATE 4— Aedeagi of *Paropsisterna simsoni*. **A**. Tasmania (TMAG F014941). **B**. Lectotype, Tasmania (NHML).

Lagerwey 2022/ (NHML) (pl. 5A). Paralectotypes. ♂, 3♀/ *Paropsis simsoni* Blackb./6542 Hob.[art]/17426, J25160, Tasmania/"suffused with met.[allic] pale gold with a suspicion of green in shimmer of citrine like [?] & costate ? Hob.[art] gold immature" [Blackburn's handwriting]/Paralectotype *Paropsis simsoni* Blackburn, 1899, des. de Little, Reid & Lagerwey 2022/ (SAM) (pl. 5C).

Other material. Tasmania. 2♂/Tas. Surrey Hills, Mayday Road, -41.47, 145.8, 11 Jan 1977, DW de Little/ Habitat description: *Eucalyptus gunnii* /TMAG F014940, F0149541, *Paropsisterna simsoni* Det. DW de Little 2020/ [TMAG], ♂/Tas. Vale of Belvoir, road in NE corner, -41.6404, 145.90753, 14 Mar 2010, DW de Little/ Habitat description: foliage of *Eucalyptus nitida*/TMAG F013377, *Paropsisterna simsoni* Det. DW de Little, 2020/ [TMAG]; ♂/Tas. Maria Is., Darlington B[ea]ch, -42.5799, 148.0643, Hand coll. S.J. Grove 10 Feb. 2019/TMAG F097848, *Paropsisterna simsoni* Det. DW de Little, 2020/ [TMAG]; ♀/ -38.9833, 148.1883, Middle Patriarch, Flinders Island, Tasmania, Australia, 24 Mar 2014, R. Raven/litter/TMAG F006751, *Paropsisterna simsoni*, Det. D.W. de Little 2020/[TMAG]; ♀/Tas. Steppes, Blackburn Creek, -42.16, 146.932, 21 Aug 1974, DW de Little/leaf litter/ TMAG F014915, *Paropsisterna simsoni*, Det. DW de Little 2020/[TMAG]; ♀/Tas. Woodsdale, Swanwick forestry coupe SW0488, -42.54135, 147.6552, Hand collection R. Bashford, 12 Dec 1979/TMAG F020154, *Paropsisterna simsoni*, Det. DW de Little, 2020 [TMAG].

Diagnosis. Live adult with disc of elytra yellow-green with paler yellow tessellations and a basal broad maroon band variably extended backwards laterally and adjacent to suture (pl. 1C, D); live and dead adult with no black pigmentation at base of head; pronotum anterior angles sharp, greater than or equal to 90°, discal puncturation much finer than marginal puncturation; elytral seriate puncturation moderately coarse and regular, interstitial puncturation much finer; ventrites and legs of dead specimens uniformly pale straw-yellow; apical third of penis broadest in lateral view slightly expanding towards shoulders with bluntly triangular apex (pl. 4A, B).

Description. Adult. Length: ♂, 7.5–8.5 mm ♀, 8–9 mm; body broadly ovate (length to width ratio 1.3) and convex (length to height ratio 2.5), with highest point at about half body length; head slightly wider than half pronotal width; elytra at anterior angles 1.3x pronotal

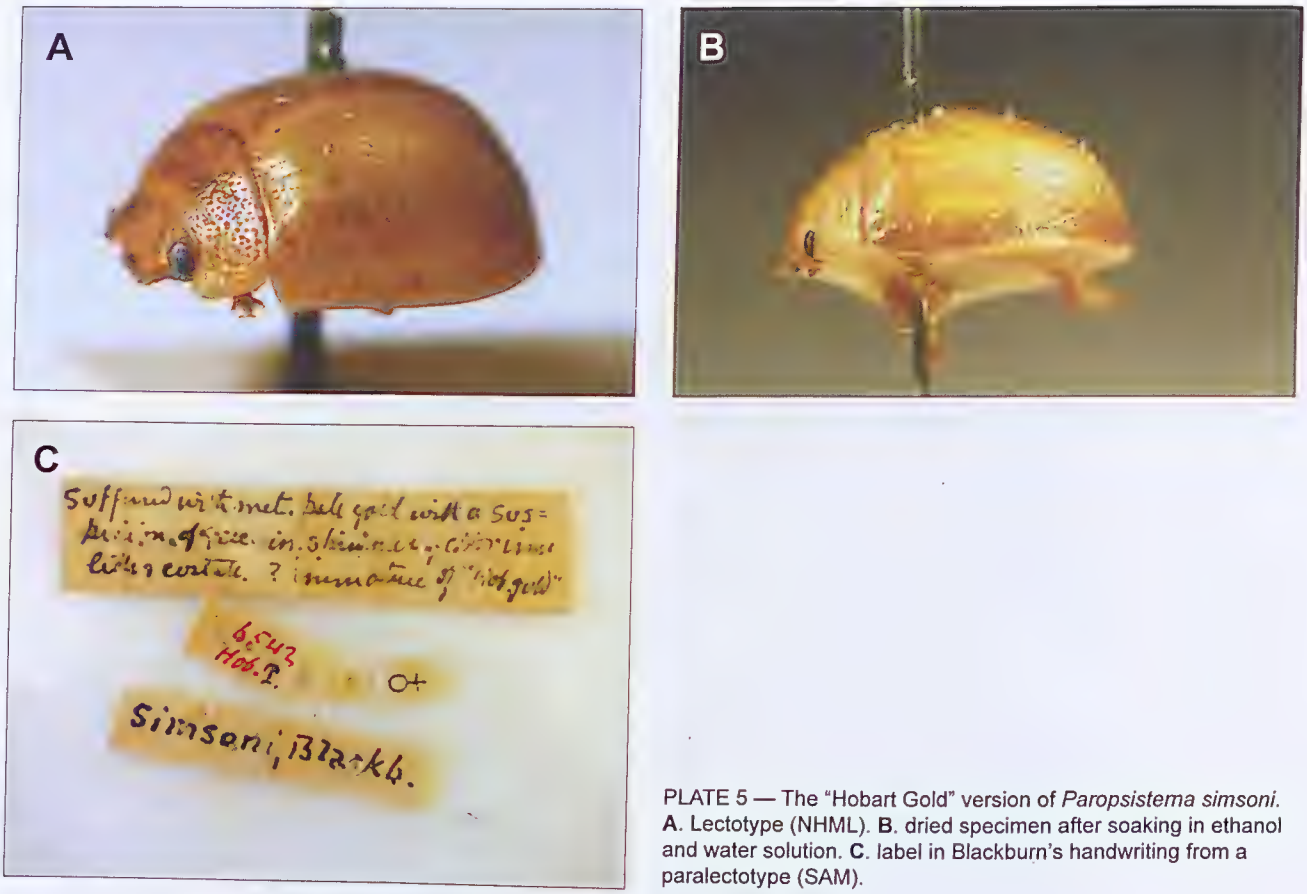

PLATE 5 — The "Hobart Gold" version of *Paropsistema simsoni*. **A**. Lectotype (NHML). **B**. dried specimen after soaking in ethanol and water solution. **C**. label in Blackburn's handwriting from a paralectotype (SAM).

width. Colour pattern of mature live beetle: translucent pale green head with black eyes surrounded by mauve red colouration, antennomeres 4–11 dark brown, pronotum pale green with variable mauve-red colouration at lateral margins, legs pale yellow green, scutellum green, elytral suture and margins pale green, elytral disc of mature adults variable yellow-green with paler tessellations and mauve-red bars at base sometimes extending less intensely over disc particularly adjacent to suture, elytral disc of teneral adults as for mature adults but paler and with less mauve red colouration. Colour of dead mature beetle; entirely yellow-brown. Pubescence: head with depressed areas adjacent to eyes with erect setae, two long setae projecting anteriorly from sides of apical margin of clypeus; rest of head, all of pronotum (including hypomera) and elytra (including epipleura) glabrous; prosternum glabrous except setose anterior margin and apex of prosternal process; mesepimera and mesoventrite glabrous except process; metanepisterna, metaventrite glabrous; abdominal ventrites glabrous except lateral margins and apex ventrite V densely setose; antennomeres 4–11 with smooth impunctate midline and raised setae either side of this; femora almost glabrous; tibiae setose; antennomeres 4–11 with smooth impunctate midline and raised setae either side of this; femora almost glabrous; tibiae setose, densely towards apices; ♂ with ovate pads of spatulate setae on pro- and meso- first tarsomeres.

Head: eyes; small, separated by c. 4x greatest widths; frontoclypeal suture broadly rounded; frontoclypeus; irregularly punctured, with mixed large (slightly larger than eye facets) and small (slightly smaller than eye facets) punctures, often coalescent in small pits, densely and finely punctured in depressed areas adjacent to eyes, more evenly sized and not coalescing at base of head; interspaces finely microreticulate; antennae; c. half body length, all antennomeres elongate, 2 shortest, 11 longest; 1 and 3 almost as long as 11, 4–11 distinctly flattened, 5–10 slightly asymmetric; labrum microreticulate, finely and sparsely punctured, apex shallowly concave; securiform apical maxillary palpomere broader in ♂, with sharper lateral angles.

Thorax: pronotum strongly transverse, width c. 2.3x length, posterior angles broadly rounded, anterior angles strongly anteriorly produced and rounded, pronotal margins entirely finely beaded; disc of pronotum (area behind vertex) punctured at head but punctures and interspaces larger, punctures increasing in size and conflation towards sides of pronotum which are rugose with irregular slightly ridged intervals; pronotal surface shining with scattered micropunctures; prosternum elevated as smooth ridge along midline, posteriorly bifurcating to follow lateral margins of process (middle of process depressed); prosternal process elongate spatulate, reaching well beyond posterior margins of procoxae; scutellum elongate semi-ovate, strongly micropunctured; elytra broadest at about middle, but with laterally prominent obtuse anterior angles (c. 120°); humeri prominent, at about 3/5 width from suture to lateral margin; scutellary striole strongly punctured, 9 distinct striae, strial punctures as large as on pronotal disc,

regularly and linearly placed; striae 4 and 5 anastomosed well before apex, remaining striae merging in large irregular punctures closer to elytral apex; intervals 1–9 and strip outside stria 9 with scattered mixed punctures, similar to pronotal disc; slightly reflexed outer margins of elytra with broad strongly punctuate area, punctures more evenly spread and larger than on pronotal disc; mesoventrite deeply hollowed anteriorly to accommodate prosternal process, small tubercle either side of hollow; mesoventrite process strongly elevated, anterior face deeply concave and posterior face (apex) deeply concave; metaventrite smooth except finely wrinkled and punctuate in lateral angles, process flat or slightly elevated; inner margins of protibiae slightly concave before apex; apical third of meso- and metatibiae with dorsal seta-fringed excavation to accommodate tarsi; male pro- and meso- first tarsomeres ovate, female elongate-triangular; claws with acute tooth on middle of ventral surface.

Abdomen: ventrites I–IV shining but finely microreticulate, close and finely punctured at base, wrinkled at sides, with sparse fine punctures elsewhere; ventrite V as I–IV, but without lateral wrinkles and more closely punctured, with subapical transverse setose groove in both sexes; apex of male ventrite V truncate with slight median convexity, apex of female broadly convex; penis in dorsal view parallel-sided from middle to obtuse-angled apex with large blunt mucron, medially broadly grooved on apical half; in lateral view slightly concave at middle, then tapering to strongly recurved mucron; flagellum not exserted.

Larva. Four larval instars (L1–4). Head capsule widths: L1: 0.8 mm; L2: 1.1 mm: L3: 1.6 mm; L4: 2.0 mm. L4 maximum length approximately 12 mm. All instars pale yellowish-green, L1 neonate mandibles, eye-spots, tarsi, egg-bursters, lateral tubercles and sclerotic plates of terminal abdominal tergites infuscate; L4 mandibles, eyespots, claws infuscate.

Egg. Elongate-oval, length 2.7 mm, width 0.9 mm, chorion tuberculate, pale green, deposited in a side-by-side raft of 5–10 on leaf lamina.

Notes. Blackburn (1899) described *Paropsis simsoni* from Tasmania. He placed it close to *P. hectica* in his key and description but distinguished it by its less shiny (nitid) appearance and different colouring: "in dried examples the whole insect pale testaceous, in living ones the disc of the elytra suffused with a rosy or golden-rosy metallic gloss" (Blackburn 1899, p. 500). Blackburn's hand-written notes attached to the type series of specimens describe this species as the "Hob. [art] gold" (pl. 5C).

In his introduction to this group of species, Blackburn (1899, p. 482) mentions the importance of knowing *"something of the colours and markings of the living insect"*. Based in Adelaide as he was at that time, most of the specimens he would have received from the more remote regions of Australia would have been dead with colours faded by the time they reached him. Immersion of such specimens in benzine or water was found to "revive the colours of a mature specimen sufficiently for the purpose (of description)".

Living specimens of *Paropsisterna simsoni*, however, could not be described as having a "golden-rosy metallic gloss". They are non-metallic pale green with the elytral disc a paler yellow flecked with whitish tessellations and a basal maroon bar which is sometimes drawn backwards adjacent to the suture. Dead specimens are uniformly pale yellow.

In soaking dead specimens in a weak solution of ethanol to soften them for genital dissection we found that the elytra took on the "golden-rosy gloss" described by Blackburn (pl. 5B). This characteristic, together with comparison of the dissected penis of the here designated lectotype with more recently collected specimens, together with other characteristics led us to the identification of de Little's (1979) "*Chrysophtharta* sp. Ch8" as *Paropsisterna simsoni*.

Blackburn (1899) based his description of *Paropsis simsoni* on five syntypes all collected at Hobart, Tasmania, four of which are held by SAM and one male, genitalia dissected, by NHML. We here designate the male held by NHML as the lectotype.

Paropsisterna simsoni is a relatively common species throughout Tasmania, including King Island and Flinders Island, where it occurs on a wide range of eucalypt species, though never in large numbers. The larvae are uniformly pale green.

***Paropsisterna vittata* (Blackburn, 1899)**
(plates 1E, 1F, 6A, 6B, 6C)

Paropsis vittata: Blackburn 1899: 508
Chrysophtharta vittata: Weise 1917: 133
Paropsisterna vittata: Reid 2006: 117

Material examined

Types. Lectotype (this designation): ♂ of carded ♂ and ♀ pair, marked 'T' on card by Blackburn/ 4612 Al. [= Australia]. [in red on card, Blackburn's handwriting]/ Blackburn coll. 1910–236/Type [printed NHML circular label]/*Paropsis vittata* Blackb. [Blackburn's handwriting]/Lectotype *Paropsis vittata* Blackburn, 1899 des. de Little, Reid & Lagerwey 2022/(NHML). Paralectotypes (3): ♀ of carded ♂ and ♀ pair/ 4612 Al. [= Australia]. [in red on card, Blackburn's handwriting]/Blackburn coll. 1910–236/Type/ *Paropsis vittata* Blackb./Paralectotype *Paropsis vittata* Blackburn, 1899 des. de Little, Reid & Lagerwey 2022 (NHML); ♂ and ♀ mounted on same pin/*Paropsis vittata* Blackb. Cotypes [Blackburn's handwriting]/Victoria [printed label]/ *Paropsis vittata* Blackb. Vic: N.S.W. cotypes [A.M. Lea's handwriting]/Paralectotypes *Paropsis vittata* Blackburn, 1899 des. de Little, Reid & Lagerwey 2022 (SAM).

Other material (11). **Tasmania:** ♂/ -42.0427, 146.3057, GDA94, W. corner "Skullbone Plains" near Lake Ina, Tasmania, 28 Feb 2012, D.W. de Little, F6190, *Paropsisterna vittata* Det. D. de Little, 2020/[TMAG]; ♂,♀/ TAS, "Surrey Hills", Bunkers Road, -41.52, 145.72, 14 Dec 1974, D.W. de Little/ *Eucalyptus delegatensis*/TMAG F14896, F14895 *Paropsisterna vittata* Det. D. de Little, 2020/[TMAG]; ♂/TMAG F33014, TAS, Mt Wellington, -42.8825, 147.2208, *Eucalyptus coccifera*, D.W. de Little,

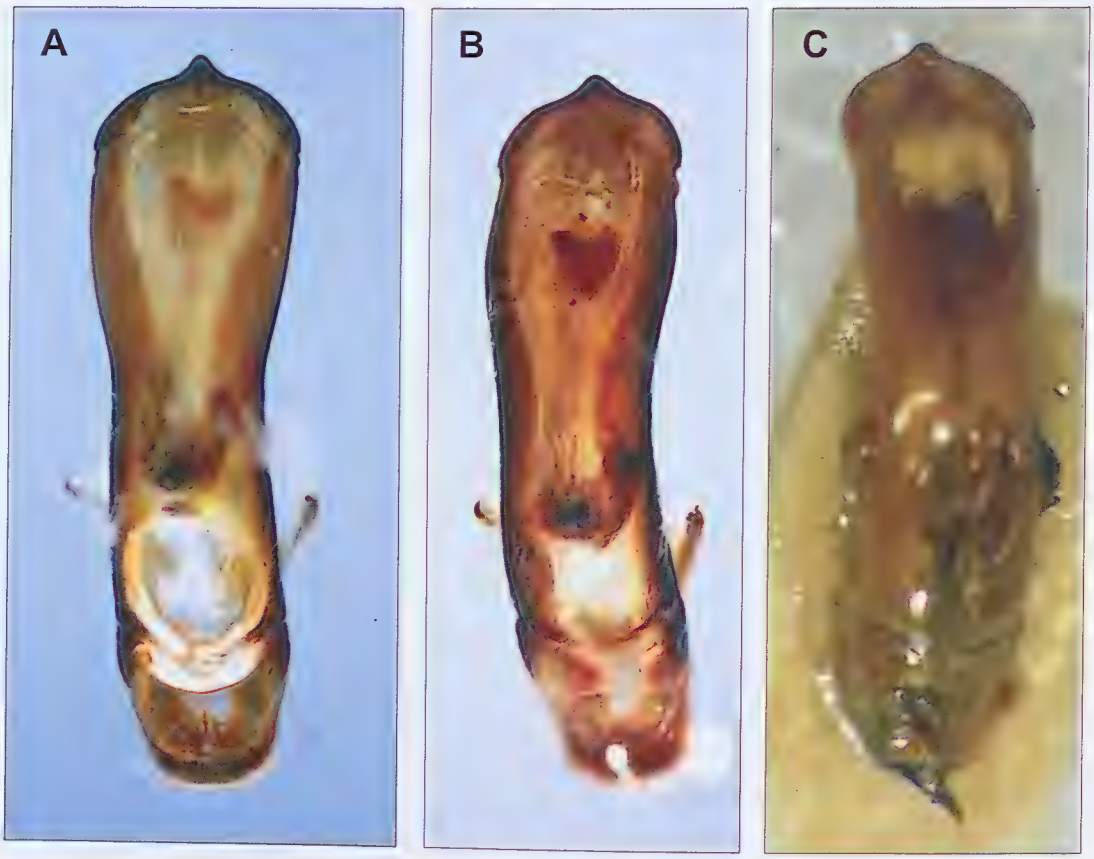

PLATE 6 — Aedeagi of *Paropsisterna vittata*. **A**. Tasmania (TMAG F14896). **B**. Victoria (TMAG F40358). **C**. Lectotype (NHML).

12 Jan 2017/*Paropsisterna vittata* (Blackburn, 1899), Det. D. de Little 2020/[TMAG]; ♂/TMAG, F40369, TAS., Wellington Ra., Knights Ck. Tk., -42.8682, 147.204, beating, col. D. de Little 28 Dec 2019/*Paropsisterna vittata* (Blackburn, 1899), Det. D. de Little, 2019/[TMAG]; **Victoria:** 5♂, 1♀/ TMAG F40358, F40361, F40362, F40363, F40366, VIC., Mt Donna Buang, -37.711, 145.878, Reared D. de Little, 14 Feb 2019/ *Paropsisterna vittata* (Blackburn, 1899), Det. D. de Little 2019/[TMAG].

Diagnosis. Live adult with disc of elytra variably pale green to dark red with paler tessellations and often with a darker broad H-shaped marking covering both elytra with the cross-bar one-third of distance from base to apex (pl.1E, 1F); dead and live adults with two anteriorly projecting extensions to black pigmentation at base of head; pronotum anterior angles more or less acute, <90°, discal puncturation nearly as coarse as marginal puncturation; elytral seriate puncturation coarse and moderately regular, interstitial puncturation much finer; ventrites and legs of dead specimens variably testaceous to dark brown; apical third of penis broadest in lateral view, expanding and then rounded towards apex with lateral notches and incurved flaps at shoulders (pl. 6A, B, C).

Description. Length: ♂, 7.5–8.5 mm ♀, 8–9 mm; body broadly ovate (length to width ratio 1.3) and convex (length to height ratio 2.5), with highest point at about half body length; head slightly wider than half pronotal width; elytra at anterior angles 1.3x pronotal width. Colour pattern of mature live beetle translucent pale brown head black at base with pigmentation produced anteriorly in two sub-central crests, antennomeres 7–11 dark brown to black (♂), pronotum pale brown, legs pale brown, black patch at distal end of femur (♂), scutellum black, elytral suture black for one third of its length to entire length from base to apex, elytral disc of mature adults variable green-gold to dark orange-red with paler tessellations and with a darker broad H-shaped fascia with the cross bar crossing elytral suture approximately one-third of its distance from base to apex, elytral disc of teneral adults clear green-gold with orange-red fascia; elytral margins translucent. Colour of dead mature beetle; entirely yellow-brown except: base of head black, lateral margins of ventrites dark brown (♂). Pubescence: head with depressed areas adjacent to eyes with erect setae, two long setae projecting anteriorly from sides of apical margin of clypeus; rest of head, all of pronotum (including hypomera) and elytra (including epipleura) glabrous; prosternum glabrous except setose anterior margin and apex of prosternal process; mesepimera and mesoventrite glabrous except process; metanepisterna, metaventrite glabrous; abdominal ventrites glabrous except lateral margins and apex ventrite V densely setose; antennomeres 4–11 with smooth impunctate midline and raised setae either side of this; femora almost glabrous; tibiae setose; antennomeres 4–11 with smooth impunctate

midline and raised setae either side of this; femora almost glabrous; tibiae setose, densely towards apices; ♂ with ovate pads of spathulate setae on pro- and meso- first tarsomeres.

Head: eyes; small, separated by c. 4x greatest widths; frontoclypeal suture broadly V-shaped; frontoclypeus; irregularly punctured, with mixed large (slightly larger than eye facets) and small (slightly smaller than eye facets) punctures, often coalescent in small pits, densely and finely punctured in depressed areas adjacent to eyes, more evenly sized and not coalescing at base of head (in black area); interspaces finely microreticulate; antennae; c. half body length, all antennomeres elongate, 2 shortest, 11 longest; 1 and 3 almost as long as 11, 4–11 distinctly flattened, 5–10 slightly asymmetric; labrum microreticulate, finely and sparsely punctured, apex shallowly concave; securiform apical maxillary palpomere broader in ♂, with sharper lateral angles.

Thorax: pronotum strongly transverse, width c. 2.3x length, posterior angles broadly rounded, anterior angles strongly produced and more-or-less sharply rounded, pronotal margins entirely finely beaded; disc of pronotum (area behind vertex) punctured at head but punctures and interspaces larger, punctures increasing in size and conflation towards sides of pronotum which are rugose with irregular slightly ridged intervals; pronotal surface shining with scattered micropunctures; prosternum elevated as smooth ridge along midline commencing adjacent to anterior margin of procoxae, posteriorly bifurcating to follow lateral margins of process (middle of process depressed); prosternal process elongate spatulate, reaching well beyond posterior margins of procoxae; scutellum elongate semi-ovate, strongly micropunctured; elytra broadest at about middle, but with laterally prominent obtuse anterior angles (c. 120°); humeri prominent, at about 3/5 width from suture to lateral margin; scutellary striole strongly punctured, 9 distinct striae, strial punctures as large as on pronotal disc, striolar and strial punctures often slightly irregularly placed (not neatly linear); striae 4 and 5 anastomosed well before apex, striae 2 and 3 and 6–8 anastomosing closer to apex, then merging with striae 1 and 9 in large irregular punctures at elytral apex; intervals 1–9 and strip outside stria 9 with scattered mixed punctures, similar to pronotal disc; slightly reflexed outer margins of elytra with broad strongly punctuate area, punctures more evenly spread and larger than on pronotal disc; mesoventrite deeply hollowed anteriorly to accommodate prosternal process, small tubercle either side of hollow; mesoventrite process strongly elevated, anterior face deeply concave and posterior face (apex) deeply concave; metaventrite smooth except finely wrinkled and punctuate in lateral angles, process flat or slightly elevated; inner margins of protibiae slightly concave before apex; apical third of meso- and metatibiae with dorsal seta-fringed excavation to accommodate tarsi; male pro- and meso- first tarsomeres ovate, female elongate-triangular; claws with acute tooth on middle of ventral surface.

Abdomen: ventrites I–IV shining but finely microreticulate, close and finely punctured at base, wrinkled at sides, with sparse fine punctures elsewhere; ventrite V as I–IV, but without lateral wrinkles and more closely punctured, with subapical transverse setose groove in both sexes; apex of male ventrite V truncate with slight median convexity, apex of female broadly convex; penis in dorsal view narrowest at middle, slightly expanded to strongly convex apex with large prominent mucron, junction of shaft with apex notched and apical margin strongly recurved either side of mucron, midline broadly grooved on apical half and at base; in lateral view apical half slightly convexly expanded, curving to explanate notched lip and strongly recurved mucron; flagellum not exserted.

Larva. Four larval instars (L1–4). Head capsule widths: L1: 0.8 mm; L2: 1.2 mm; L3: 1.7 mm; L4: 2.1 mm. L4 maximum length 14 mm. L3–4 broadest at mid abdominal segments. L1–3 head capsule, legs and lateral body tubercles black, L4 pale greyish brown with reduction of black pigmentation on head capsule, legs and lateral body tubercles.

Egg. Elongate oval, length 2.8 mm, width 1.1 mm, chorion tuberculate, white or orange-pink, deposited in a side-by-side raft of 5–10 on leaf lamina.

Notes. Blackburn (1899) described *Paropsis vittata* from the Australian Alps of Victoria and New South Wales.

Tasmanian specimens were misidentified as "*Chrysophtharta simsoni*" by de Little (1979) based on Blackburn's (1899) description of living specimens having the "disc of the elytra suffused with a rosy or golden-rosy metallic gloss" and its "somewhat less nitid surface" than *Paropsis aurea*. Living and dead specimens from mainland SE Australia (including Blackburn's syntypes) and Tasmania have now been examined, including dissection and examination of the penis and rearing of immature stages and there is no doubt that the Tasmanian form is conspecific with mainland *Paropsisterna vittata*.

Blackburn (1899) based his description of *Paropsis vittata* on four syntypes, a male and female pair held by NHML, and a male and female pair held by SAM. The male with genitalia dissected held by NHML is here designated the lectotype.

Paropsisterna vittata (pl. 1 E, F) somewhat resembles *P. selmani* Reid and de Little, 2013 (pl. 1G, H) in live colouration and form. Live adult specimens of the latter species are easily distinguished by the elytral apical diamond-shaped marking. Larvae of *P. selmani* have black head capsules and a dark lateral band whereas larvae of *P. vittata* are without these features.

Paropsisterna vittata occurs in the alpine to sub-alpine regions of Tasmania. It has been abundant in recent summers on *Eucalyptus coccifera* close to the summit of kunanyi/Mt Wellington. In Victoria the species is confined to high elevation.

CONCLUSION

The identity of the epithetical "Hobart Gold" is solved. It is not *Paropsisterna aurea* which is found to be a junior synonym of *P. hectica*, and it is not *P. vittata* which occurs in Tasmania as well as in its type locality, the Australian Alps. *Paropsisterna simsoni*, the "Hobart Gold", is when living, the least golden of the three species.

ACKNOWLEDGEMENTS

The authors thank the following curators and colleagues for their assistance in this project: Di Moyle, Simon Grove and Cathy Byrne (TMAG), Michael Geiser (NHML), Cate Lemann (ANIC) and Matthew Shaw (SAM). Tony Daley, the late Vin Patel, and the late Ted Prichard provided images.

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(accepted 3 June 2022)

WHAT'S IN A NAME? – MT GEIKIE AND THE RECOGNITION OF GLACIATION IN TASMANIA

by Peter Baillie

(with four figures, two plates and one appendix)

Baillie, P. 2022 (i:xii): What's in a name? – Mt Geikie and the recognition of glaciation in Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 156: 43–00. ISSN: 0080-4703. School of Earth Sciences, University of Western Australia, Perth, WA 6009, Australia. Email: peter.baillie@uwa.edu.au

Although glaciation of the Tasmanian highlands was recognised by early explorers, it was in the 1890s that Edward Dunn and Thomas B. Moore provided the first formal descriptions and maps – the Lake Dora–Tyndall Range glaciated area in western Tasmania. The Victorian geologist E.J. Dunn published the first map in 1893 with a description of glacial features of the Lake Rolleston–Lake Dora area. Moore described glacial features over a larger area than Dunn, including the Tyndall Range, and named one of the mountains in that area, Mount Geikie, in honour of pioneering work on glacial geology that had been carried out in the British Isles. Publication of Moore's paper caused quite a colonial stir; in particular, Moore's claim to be the first to record evidence of (Quaternary) glaciation in Tasmania. In fact, neither Dunn nor Moore were the first to observe the effects of glaciation though they presented the first early maps of glaciation of the Lake Dora–Tyndall Mountains area of the West Coast Ranges.

Key Words: Archibald Geikie, James Geikie, Charles Gould, Thomas B. Moore, Edward Dunn, Tyndall Range, glaciation, Tasmania.

INTRODUCTION

Almost a quarter of Tasmania has been granted World Heritage listing by UNESCO, partly in recognition of the island's impressive glacial landforms; the legacy of numerous phases of Quaternary and older glaciation (summarised in Colhoun *et al.* 2010). The recognition of that glaciation has interesting historical connections with the mid-nineteenth century geological controversy that surrounded the establishment of the glacial theory in the British Isles (Banks *et al.* 1987).

The West Coast Range features prominently in the Tasmanian landscape and in the history of recognition of the island's glacial legacy. The range owes its topographic prominence to its underlying geology, comprising a succession of resistant, non-marine conglomerate-sandstone-mudstone siliciclastics – the Late Cambrian to Early Ordovician Owen Group and its correlates – flanked by Cambrian largely felsic volcanic and sedimentary rocks (summary in Seymour & Calver 1995). Several phases of glaciation occurred in and around the range during the Quaternary, and during the Last Glaciation a small ice cap accumulated on the Tyndall Range and extended across the Lake Dora Plateau towards the Eldon Valley (Colhoun 1985, fig. 1 in Baillie 2010).

The Tyndall Range (with Mount Tyndall at its northern end), some 15 km north of Queenstown, lies between Mount Sedgwick and Mount Murchison in the West Coast Range. Mount Tyndall was named by the Honourable James Reid Scott MLC in 1877 in honour of English physicist and glaciologist John Tyndall (Baillie 2010) while Mount Geikie, a mountain at the southern end of the Tyndall Range (figs 1, 2), was named by Thomas Bather Moore around 1894 (Moore 1894). It was assumed to have been named after eminent British geologist Sir Archibald Geikie although there was a possibility it could have been named after his younger brother, James (Baillie 2010).

Since its recognition, the glacial history of Tasmania has been important far beyond the shores of the island. The great naturalist Alfred Russell Wallace (the co-discoverer, with Charles Darwin, of evolution by means of natural selection) published a paper in *Nature* summarising, reasonably well, the situation in Tasmania as it was in 1893 stating:

> *... it is much to be wished that a more detailed account of this interesting district, with a good map showing all the mountains, lakes, and valleys referred to, would be given us by one of the local geologists.* (Wallace 1893, p. 4)

On 24 January 1894 Professor James Geikie wrote to Professor Chamberlain of Chicago informing him that he had nearly completed a new edition of *The Great Ice Age* and that:

> *... some very remarkable evidence has turned up recently in Tasmania ...* [and that] *... geologists will have to reconsider their notions as to glaciation of our Antipodes in the light of the newly discovered evidence.* (Newbegin & Flett 1917, p.120)

In this paper the term 'British Geological Survey' is used in the modern sense, that is, for the United Kingdom, and is used instead of the evolving, and sometimes geographically disparate, terminology of the nineteenth century.

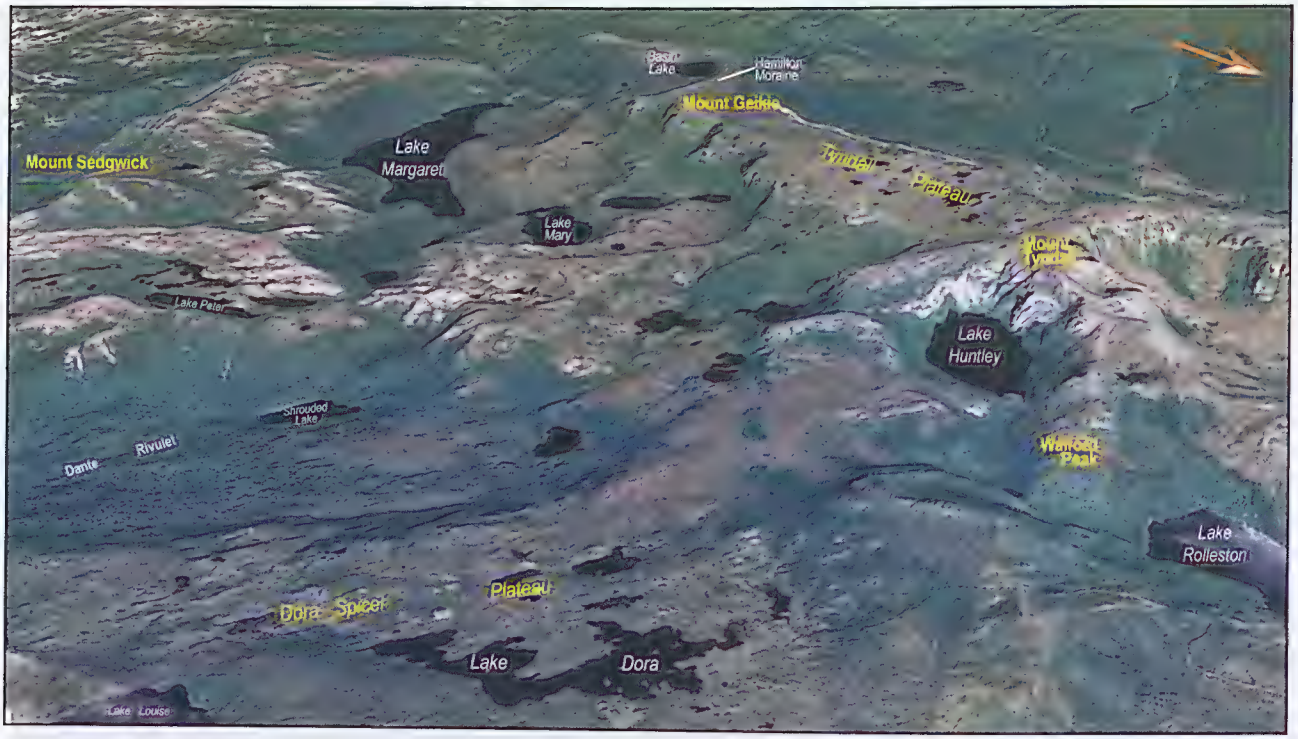

FIGURE 1 – Oblique aerial view to the southwest of Spicer–Dora Plateau towards the Tyndall Plateau (Google Earth image); distance from Mt Sedgwick to Lake Huntley is approx. 8 km.

FIGURE 2 – Mt Geikie and the Tyndall Range, view from the summit of Mt Sedgwick (observed by T.B. Moore on 23 October 1892); distance from Mt Geikie to Mt Tyndall is approx. 3 km.

DUNN AND MOORE: CONTRIBUTIONS TO THE 'DISCOVERY' OF QUATERNARY GLACIATION IN TASMANIA

In September and October 1892 geologist Edward John Dunn (pl. 1D, appendix 1), working with prospector and naturalist Thomas Bather Moore (pl. 1C, appendix 1), spent about ten days undertaking geological studies on copper mineralisation around Lake Dora (Crawford 2020), and recognised the effects of glaciation around Lake Rolleston and Lake Dora. Dunn presented his version of the discovery to the Royal Society of Victoria the following year: a paper on the glaciation was read on 8 June and published in the 1893 *Proceedings* (Dunn 1893). Dunn described moraines, erratics and the physical effects of ice between Lake Rolleston and Lake Dora; his map is shown as figure 3. The maps of Dunn and Moore are not only archival for the glaciation of the Tyndall Range–Lake Dora area, but they are also cartographically archival for this part of Tasmania. Since there were no topographic maps available for western Tasmanian mountains in the late 1800s the cartography uses the old method of hachures to represent topography. The hachure stroke is aligned with the slope and thickens upslope to produce bands that emphasise the increasing altitude of the hills. It preceded the use of the contour, which did not become widely used until after the mid-1800s, but such adequate base maps with contours would not have been available for the maps of Dunn and Moore.

Immediately following the return of Dunn to Melbourne, Moore revisited the Sedgwick–Tyndall area to further study the effects of the glaciation and climbed Mount Sedgwick on 23 October 1892 (Crawford 2020). He presented a paper on the 'discovery' of glaciation in Tasmania to the Royal Society of Tasmania in April 1893, with publication in 1894 (Moore 1894); supplementary notes on areas to the south of Mount Lyell were included with the printed paper. Moore was resident at Strahan at the time and the paper was read by the Secretary (Mr A. Morton; appendix 1). In the paper, Moore presented a map illustrating the extent of glaciation in the Tyndall Range–Lake Dora area (fig. 4) and showed Mount Geikie, noting that the name had not at the time been officially sanctioned.

Moore stated that in 1892 he and Dunn had observed the effects of glaciation on the plateau near Lake Dora and that he had subsequently extended this recognition into the Tyndall Range–Mt Sedgwick area (Moore 1894). In the paper he described both erosional and depositional features, including the spectacular Hamilton Moraine immediately west of Lake Margaret (fig. 1). Furthermore, Moore noted that he had recognised glaciation in the Eldon Range–Mount Gell area 'as far back as 1883, in a report to the Government of an exploration to the West Coast' (Moore 1884, p. 148).

THE GEIKIE BROTHERS AND THEIR CONTRIBUTION TO GLACIAL GEOLOGY

Sir Charles Lyell and Sir Roderick Murchison (after whom Mount Lyell, north of Queenstown, and Mount Murchison, towering above Rosebery in western Tasmania, are named), were giants of nineteenth-century geology (see brief biographies and photos in Baillie 2010) whose opinions were sought, digested and accepted with little dissent. Lyell was willing to agree to the former existence of glaciers over very extensive regions of the British Isles and described moraines that occur in the upland valleys of Scotland but considered the 'drifts' (now known as boulder clay or till) as being deposited in cold seas in which icebergs floated. Murchison had agreed with Lyell and disagreed with Swiss geologist Louis Agassiz (1807–1873) who had proposed that a great ice sheet had covered much of Western Europe and the British Isles (Agassiz 1840, Newbigin & Flett 1917, Summerhayes 2019).

Archibald Geikie (pl. 2A, appendix 1) was employed by Murchison, newly appointed head of the British Geological Survey, as a mapping assistant in 1856. His interest in glacial geology commenced in 1859, when working in association with Andrew Crombie Ramsay (after whom Mount Ramsay in western Tasmania is named (pl. 2C, appendix 1), he realised that Lyell was wrong. Geikie's field mapping of the drift-covered central area of Scotland identified sediments and bedrock surfaces that he could not adequately explain by a submergence mechanism (Geikie 1863a) and concluded that much of the Northern Hemisphere was covered with ice and snow, like the present ice cap of Greenland (Worsley 2019). Geikie read a paper to the Geological Society of Glasgow on 20 November of that year, which was reprinted as a booklet in 1863 to encourage students in Scotland to follow up his ideas (Summerhayes 2019). Among Geikie's evidence were radiating striations on bedrock, *roche moutonnées*, with their smooth faces upstream and their craggy faces downstream, U-shaped valleys leading into lochs, and the ubiquitous boulder clay.

James Geikie (pl. 2B, appendix 1) joined the British Geological Survey in 1862 under the supervision of his brother and was charged with mapping surficial deposits in the Scottish landscape. While studying these deposits, he believed he had found evidence of warmer periods (interglacials) punctuating successive colder periods, or ice ages. Having little conclusive evidence, he hesitated at first, but growing evidence from studies of continental Europe convinced him he was correct. He was also strongly influenced by Ramsay, then a local director of the British Geological Survey.

In 1865 the brothers gained firsthand experience of current glacial processes in Arctic Norway during an expedition organised by Archibald. They jointly concluded that land-ice glaciation held the key to interpreting the 'drift' (Worsley 2019). The brothers thought that the clay of boulder clay is eroded from the ground by the action of ice sheets on land and left behind as the ice melted. This ground moraine is quite different from 'end moraines' –

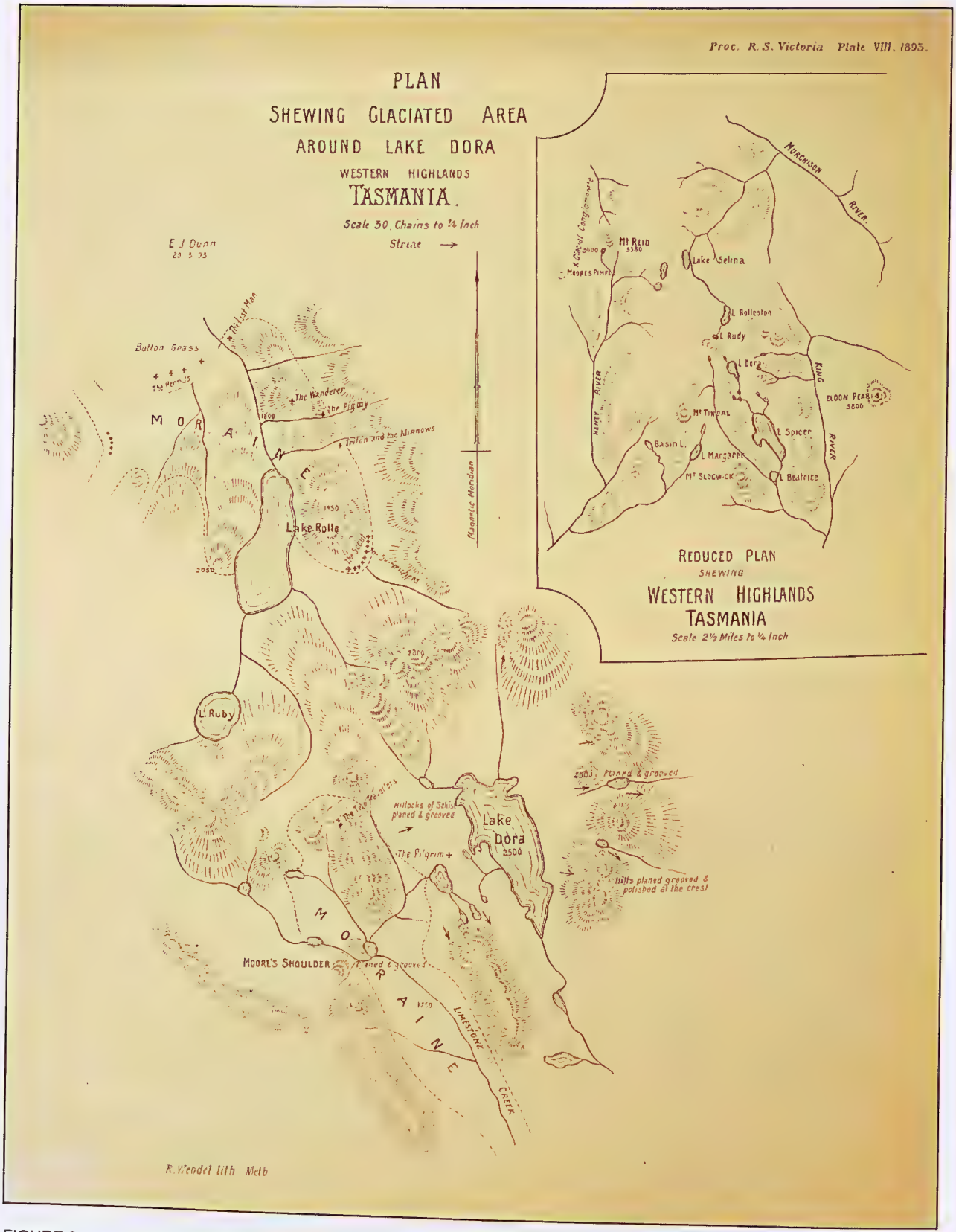

FIGURE 3 – Dunn's map of Lake Dora glacial features (Dunn 1893).

the piles of debris dumped at the terminations of glaciers or ice sheets (Summerhayes 2019).

Archibald Geikie's observations of the early 1860s took a long time to be widely accepted because Lyell's theory had been endorsed by other influential figures, such as Murchison. Only with the immaculate fieldwork and global compilations of James Geikie in the 1870s, was Archibald Geikie vindicated and the fallacy exposed of believing that the 'drift' of Europe and North America originated from icebergs (Summerhayes 2019).

James Geikie accumulated a vast worldwide store of knowledge of the geology of the glacial and interglacial periods of the Ice Age, publishing his findings in *The Great Ice Age* (Geikie 1874), a year before Lyell died, and while Lyell, nearing his death, was compiling the twelfth and final edition of his *Principles of Geology* in 1875. Perhaps it is not surprising that James's results do not feature significantly in Lyell's book. Lyell had read Archibald Geikie's 1863 publication and the final edition of *Principles* largely accepted the Ice Age hypothesis – at least for Switzerland and other mountain regions (Summerhayes 2019).

REACTION TO DUNN AND MOORE'S 'DISCOVERY'

It would appear the reading and publication of Moore's paper caused quite a stir in colonial Tasmania; in particular, Moore's claim to be the first to record evidence of (Quaternary) glaciation in Tasmania, all faithfully recoded in (and between the lines) of *Papers and Proceedings of the Royal Society of Tasmania* for 1893 (issued June 1894).

The Government Geologist of the day was Alexander Montgomery, appointed by the Tasmanian Government as Inspector of Mines and Geological Surveyor in 1889 (appendix 1, Bacon 2013). He did not attend the meeting at which Moore's paper was read but was shown a copy by the Society Secretary and wrote 'a few notes' (ten-and-a-half printed pages; Montgomery 1894) firmly putting Moore in his place. Montgomery was somewhat dismissive that Moore had published the first observations about Tasmanian Quaternary glaciation and noted that others including R.M. Johnston, C.P. Sprent and indeed himself had noticed evidence of glaciation (without publishing anything significant). Montgomery (*op. cit.*) described the country between Barn Bluff and the Lake Dora Plateau and concluded that the land had been sculpted by ice action at a 'comparatively recent date'. He then went on to state glaciers would have been present in other highland areas including Ben Lomond, Mount Wellington and the Central Plateau.

Montgomery (1894, p. 161) does not mince his words about Moore:

> *I cannot think it all probable that Mr. Moore is correct … I have little doubt that when he comes to examine the country more thoroughly … It is hardly conceivable…which is what Mr. Moore's words seem to imply … Before accepting such a theory, we should first …".*

Montgomery concluded by referring to the work of R.M. Johnston (appendix 1) whom he said regarded the glaciers as having been of 'small extent'. Johnson had been present at the April meeting at which Moore's paper was read and had observed that 'its title was rather unfortunate, inasmuch that one of the main facts known for 30 years in connection with the Western Highlands was the abundant evidence of glaciation'.

Johnston had evidently also been stirred into action as the paper titled 'The Glacier Epoch of Australasia: Review of the evidences of former glaciation in Australasia, with critical observations upon the principal causal hypotheses which have been advanced to account for glacial epochs generally' was read to the Royal Society of Tasmania on 13 June 1893 and published in the 1894 *Proceedings* (Johnston 1894). Johnston noted that contributions such as those of Moore and Montgomery 'arouse us from our favourite grooves, and recall our attention, for a time at least, to that large and important phase of *Dynamical Geology* known as Glacial Action' (Johnston 1894, p. 75).

Johnston (1894) examined the various types of evidence of former glacial action (moraines, erosional features, till, erratics etc.) and then discussed evidence of former glaciation in New Zealand, mainland Australia and Tasmania where he noted that Charles Gould was the first to have 'drawn attention to the abundant evidence of glacial action in western Tasmania' but noted that although Gould had 'left no special memoir', he made a verbal communication to the Honourable James Reid Scott (pl. 1B, appendix 1), formerly Chief Secretary of Tasmania (Johnston, *op. cit.* p. 92–93). Johnston went on to detail trips to western Tasmania where he was able to confirm Gould's earlier observations and having recorded the results in his monumental work entitled *The Geology of Tasmania* (Johnston 1888, discussed below). Johnston somewhat disdainfully noted that the 'conclusive evidence' had so impressed him he was 'content to summarise them merely as a general conformation of the previous observations of Messrs. Gould and Sprent' (p. 97). Johnston then summarised the 1885 publication of Charles Sprent (Sprent 1885), who had described erratics and 'traces of glacial action' in the Mackintosh Valley (p. 98). Johnston was at pains to point out that Moore's claim to be the first to recognise glaciation was incorrect, but his paper did provide a valuable addition to the general knowledge.

Johnston (1894) noted that he had the 'privilege' of reading Montgomery's 'able' paper before it had been presented and that the contribution was not only most interesting but 'greatly extends' the knowledge of glacial phenomena in Tasmania. Furthermore, Johnston was gratified to find that Montgomery's 'extended and independent' conclusions were similar to his. Some quotes make interesting reading:

> *I had thus ample opportunities for observing the many evidences of former glaciation in these regions, enabling me to confirm the earlier observations of Mr. Gould, and also enabling me to record the general results of such observations in my work on the 'Geology of Tasmania' … I only gave my general conclusions in this work,*

PLATE 1 – Portraits of **A.** Charles Gould, **B.** James Scott, **C.** Thomas Bather Moore and **D.** Edward Dunn. (Images sourced from texts quoted.)

> *although my notes contained particulars regarding the abundant occurrence of moraines, roche-moutonnée, scooped tarns and lakes innumerable, huge ice-born erratics, polished rock surfaces.* (Johnston 1894, p. 96)

> *No one, however ignorant of glacial action, could in this neighbourhood gaze upon those beautiful scooped, or rather abraded, lakes or tarns without being impressed with the idea that its singularly characteristic features must have been produced by the slow rasping flow of an ancient river of ice.* (Johnston 1894, p. 97)

> *The abundance of conclusive evidence so impressed me I was content to summarise them merely as a general confirmation of the previous observations of Messrs. Gould and Sprent.* (Johnston 1888, p. 97)

Despite what he might have said or implied in his rebuttal of Moore, nowhere in Johnston's *The Geology of Tasmania* does he discuss or describe glacial deposits or landforms in Tasmania, noting (Johnston 1888, p. 326) 'little evidence of physical disturbances of an extraordinary character during the (Quaternary) period, if we except the minor oscillations of land indicated by the raised beaches on the islands of Bass's Strait and on other places along the northern coastline of Tasmania'.

Johnston damns the work of Moore (and Dunn) with faint praise:

> *It is evident, therefore, that the recent account of all the characteristic phenomena of glaciation observed in 1892 and 1893 by Messrs. Dunn and T. B. Moore in the same region, that is in the neighbourhood of Mounts Tyndall, Sedgwick, and Murchison, and charted so clearly on Mr. T. B. Moore's accompanying maps, confirm Messrs. Gould, Sprent, … earlier observations; and although the later observers, Dunn and Moore, write as if they were unacquainted with the much, earlier observations of the persons named,*

PLATE 2 – Portraits of **A.** Archibald Geikie, **B.** James Geikie, **C.** Andrew Crombie Ramsay and **D.** John Tyndall. (Images sourced from texts quoted.)

> *as well as of the descriptions to be found in my work on the Geology of Tasmania, it does not detract in the smallest degree from the valuable additions which they have made to our knowledge of the evidence of former glacial action in the alpine regions of western Tasmania.* (Johnston 1894, p. 99)

He is fulsome in his praise of the work of Montgomery:

> *The able paper by Mr. A. Montgomery, M.A., Government Geologist, which has been read to us this evening, I had the privilege of reading beforehand. It contains a very interesting account of his recent geological observations, many of which are new and extremely interesting; but, above all, it not only greatly extends our knowledge of glacial phenomena in Tasmania.* (Johnston 1894, p. 100)

Johnston was obviously familiar with the ongoing Northern Hemisphere work on glacial geology – he referred to the work of 'Geikie' but appears to have been unaware that there were two: in *The Geology of Tasmania* he reviewed glaciation in Britain and Europe and referenced 'Geikie's Text Book of Geology' (p. 297) – this is a work by Archibald Geikie (Geikie 1882). He subsequently (p. 298) referred to 'the same talented writer, in his remarkable work, "The Great Ice Age and its Relations to the Antiquity of Man"' – this, in fact, the work of James Geikie (Geikie 1874).

In the 1894 rebuttal of Moore, he referred to James Geikie's 'seminal work on the Ice Age' (that is, Geikie 1874) and refers to the 'very able address recently delivered by Professor J(ames) Geikie'.

Johnston (1894) concluded that the 'glacier epoch of Australasia was probably comparatively mild in its effects, manifesting itself mainly by increased rainfall in lowlands, and by establishing local glaciers in the alpine regions of Southern Australia and Tasmania, and in greatly extending the spread of the existing snowfields and glaciers of the New Zealand Alps' and that 'in Tasmania it is most probable

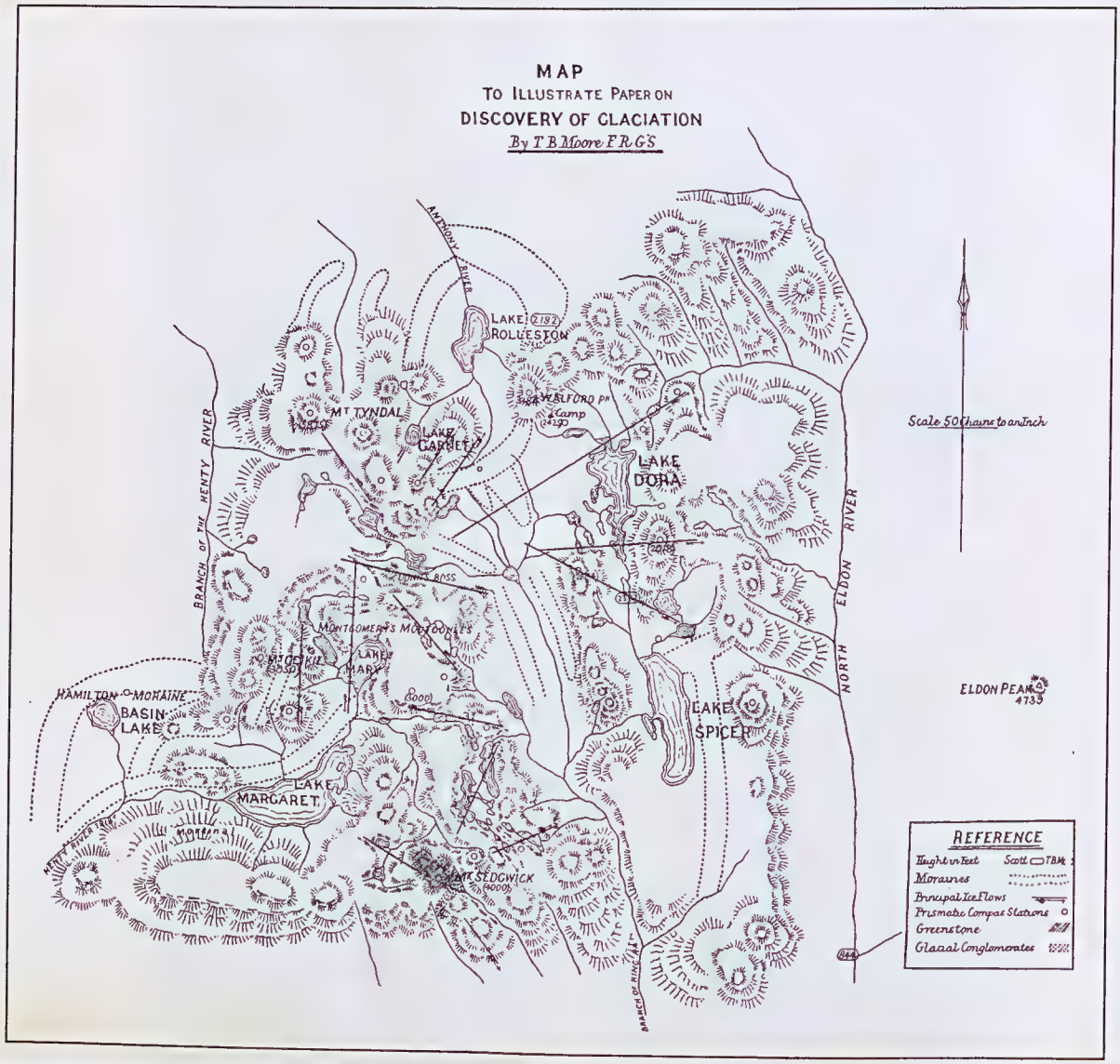

FIGURE 4 – Moore's map of Tyndall Range and Dora–Spicer Plateau glaciation (Moore 1894).

that only on the western slopes of our Western Highlands was there sufficient precipitation to yield glaciers, any of which did not reach the sea, and probably were melted within their own valleys before reaching the 1,000 feet level' (Johnston 1894, p. 130).

THE CONTRIBUTIONS OF CHARLES GOULD AND CHARLES PERCY SPRENT

On the recommendation of Sir Roderick Murchison, Charles Gould (pl. 1A, appendix 1) was appointed by the Tasmanian Government as Geological Surveyor in 1859 and undertook three epic journeys to western Tasmania between 1860 and 1863 (Binks 1980). He recognised that glaciers had been present in the highlands in the (recent) geological past and in the report of his first expedition he suggested (Gould 1860) that large, transported, boulders of 'greenstone' (Jurassic dolerite) in the Cuvier and Collingwood valleys may have been moved by glacial action and recognised a possible moraine at the lower end of the Cuvier Valley, immediately west of Lake St Clair. He noted, however, that recognition of glaciation was not the primary purpose of his expedition and was not supported by 'very convincing evidence' (Gould 1860, p. 11).

Gould may have left a clue to his thinking with the naming of the Chamouni Valley (now known as the Linda Valley), between Mounts Lyell and Owen in western Tasmania. The Linda Valley is a typical glacial U-shaped valley and Linda Creek is a misfit compared to the valley in which it sits. Moore (1894) described glacial deposits from the valley in supplementary notes to his 1894 paper; it is now known that multiple phases of glaciation have occurred in the valley during the Pleistocene (Barbetti & Colhoun 1988, Colhoun *et al.* 2010). Gould named the valley in 1862 – he mentions it in a letter published in

the Hobart *Mercury* on 14 May 1862. It is not shown on the 1862 hand-drawn map produced after his 1862 expedition (Baillie 2010) but is shown on a compilation map dated 1862 in the Tasmanian Archives (accessed at https://stors.tas.gov.au/AF928-1-47) which was copied on an 1865 German map (Peterman 1865). The Chamouni area of eastern France, immediately north of Mont Blanc, was well known in the mid-nineteenth century for its ongoing and past glacial history; for example, Lyell mentions the area in his *Principles of Geology,* Tyndall (1860) refers to the area and several papers in Forbes (1859) compilation of papers on glaciers report work from the Chamouni area.

Alternatively, and most credibly, Blainey (1954) suggested that Gould may have named the stream and valley after the (then) recent opera set in Savoy (which includes the Chamouni area), *Linda di Chamounix*, by Italian composer Gaetano Donizetti (1797–1848).

Charles Percy Sprent, a trained surveyor with good knowledge of geology and mineralogy, opened the route to the mineral areas of central western Tasmania following the discovery of tin at Mount Bischoff in the early 1870s (Binks 1980). He described glacial debris, including very large granite boulders, in the Mackintosh River representing deposits from a glacier which had originated from the Cradle Mountain–Barn Bluff area and noted that 'traces of glacial action are common all over the West Coast in localities close to high mountains' and that the same indications were found in the King and Franklin rivers valleys (Sprent 1885).

MOORE'S RESPONSE AND OLDER GLACIAL DEPOSITS

Moore responded the following year (paper read 14 August 1894; published as Moore 1896) stating that he had been aware of the 'evidence' of boulders and various theories put forward but that he believed Dunn had been the first to bring forth 'indisputable proof' of 'prehistoric' glaciation. He went on to state that he had observed granite and 'greenstone' erratics near Lake Dixon (headwaters of the Franklin River, lying between Mounts Rufus and Arrrowsmith) in 1883 and that this had been recorded in his report to the Government (Moore 1883) where he had stated 'the accumulation is composed of every variety of rock…[and that]…these masses of greenstone have been brought, in the glacial period, from the higher lands of Mount Gell, or the Eldon Range, and deposited by that agency in their present resting place' (Moore 1883, p. 5).

Moore spent considerable written effort describing a mixture of what he considered to be 'glacials', but are now known to be Quaternary glacial deposits, Tertiary continental deposits and Permo-Carboniferous glacio-marine sedimentary rocks. He had recognised (Moore 1894, p. 148) a much earlier glacial episode in rocks cropping out below the summit of Mount Sedgwick and described conglomerate and coal measure rocks 'intermixed with carboniferous fossils' and suggested these represented an event much older than the glacial period which he had previously described. His words are open to interpretation, but I believe he had recognised the Late Carboniferous glaciogenic deposits where cobble and pebble conglomerates and pebbly sandstones occur in pre-existing topographic depressions in older rocks (Banks & Ahmad 1962; unpublished work of the author on Lyell 1:50 000 map sheet).

In his subsequent paper, Moore (1896) described 'glacial deposits' from the King River and the Queenstown–Strahan Road. The succession near the King River is a mixed continental succession which has yielded an Eocene microflora from coaly material above a dolerite-bearing conglomerate (Cox, *in* Baillie & Corbett 1985); the tillite on the Queenstown–Strahan Road is part of a Late Carboniferous glacial succession which crops out between Strahan and the Henty River (Baillie & Corbett 1985).

DISCUSSION

Thomas Bather Moore completed his education at Windermere College in the English Lake District under the guardianship of his uncle Harry Moore, returning to Tasmania in 1868 (McShane 1986). Encouraged and accompanied by his uncle, Moore developed an interest in botany and geology, and walked and climbed throughout the Lake District (Crawford 2020).

The Lake District is an upland area in northwest England with numerous expressions of glacial activity, and many studies undertaken over nearly two centuries. Adam Sedgwick (for biographic notes and image see Baillie 2010) was the first to describe 'alluvium' and 'diluvium' in the area (Sedgwick 1825) with a glacial origin for erosional landforms and deposits first proposed by William Buckland (1840). The British Geological Survey commenced systematic mapping in 1866, assembling much empirical information and completing their work in 1888. They 'wrote extensively on glacial matters, glacial phenomena by then being easily recognizable to the professional eye' (Oldroyd 2002, p. 257), and mapped large areas of 'drift'. By 1870 the glacial history of the area was being actively debated, some eight papers being published on the topic that year.

Given the contemporaneous activities of the Survey and the keen naturalist influence of his uncle, it is highly likely that the young Thomas Moore received a strong field-based education in glacial geology in the Lake District.

Moore had recognised the effects of glaciation in Tasmania some time before 1893 but it was not until he returned to Lake Dora with Dunn, who had previous experience with glacial geology, that he realised the importance of what he had previously observed and then used Dunn's credibility to strengthen his own work. This is confirmed by his return to the Tyndall Range immediately after Dunn's departure.

Moore left no clues after whom he had named Mount Geikie.

The contribution of Archibald Geikie to glacial geology was limited as he authored only two research papers and a popular review devoted exclusively to the subject (Worsley

2019: Geikie 1863a, 1863b, 1865). James Geikie's major volume on glacial theory, *The Great Ice Age*, was initially published in 1874, nearly five years after Moore had returned to Tasmania but it is certain the volume was available in Tasmania, possibly through the Royal Society of Tasmania, as it was quoted by Johnston.

The Royal Society of Tasmania played an important role in the Colony, providing a forum for discussion, means of communication and resources for education. In a letter written to his father (the famous ornithologist John Gould) on 20 April 1872, Charles Gould indicated the importance of the library maintained by the Royal Society of Tasmania noting it to be the source of 'many excellent scientific papers' and 'indispensable to us' and seeking his father's help to assist with obtaining reference books (Gould correspondence, State Library of New South Wales 2010).

It has already been noted that Robert Johnston was apparently unaware there were two Geikies; it could well be that Moore was also unaware. Given the importance of James Geikie's book *The Great Ice Age*, it is likely that this was on Moore's mind when he named the mountain. It doesn't matter, both brothers made significant contributions to glacial geology and the naming of the mountain is a fitting tribute to both.

In the context of recognition of glacial phenomena, it is worthwhile to consider the naming of Mount Tyndall (at the northern end of the Tyndall Range), which had been named by the Honourable James Reid Scott MLC in 1877. In a letter to the Minister for Lands and Works, Scott stated that he had named Mount Tyndall 'an appropriate continuation of the sequence of names of eminent men of science given by Gould to the peaks of the West Coast Range, of which it is one'. Scott had been in the Tyndall–Dora Plateau area in 1877 and had encountered T.B. Moore where they certainly discussed geographic nomenclature (Binks 1980, Crawford 2020).

Scott had been to the southwest of Tasmania in 1871, but the 1877 trip was his first trip to the Dora–Tyndall area. Although he had been a Fellow of the Royal Society of Tasmania since 1868 and had access to the latest scientific publications, it is hard to see why he would have named a feature after the relatively obscure John Tyndall (pl. 2D, appendix 1) when there were arguably much more eminent names available – unless the glacial origins of the Dora–Tyndall area had been recognised and Tyndall's name bestowed in honour of his work on glaciation in the Alps (Tyndall 1860). It is possible that Tyndall's name was suggested to Scott by someone else and Baillie (2010) speculated that Moore might have suggested the name.

Moore's assertion that he and Dunn had 'discovered' evidence of past glaciation in Tasmania was undoubtedly incorrect, although Dunn and Moore were certainly the first to properly describe what had been observed. There was, however, a concerted attempt to downplay Moore's work and its significance. Montgomery (1894) stated that Moore's (then) forthcoming paper was brought to his attention by the Secretary of the Royal Society of Tasmania and was somewhat dismissive that Moore had published the first observations about Tasmanian Pleistocene glaciation, noting that others including R.M. Johnston, C.P. Sprent and himself had noticed evidence of glaciation. It should be noted that Gould's final journey to western Tasmania concluded in June 1863, the same year as Archibald Geikie published his seminal research papers on the glaciation of Scotland and so it is unlikely Gould was aware of the most recent work.

Between 1922 and 1945 A.N. Lewis (Lewis 1944) developed a threefold glaciation model based on evidence from western Tasmania, but it was not until the past 40 years and the work of Eric Colhoun and his collaborators (Colhoun *et al.* 2010 and references therein) that the multiphase Quaternary glaciation of Tasmania has been properly described and established. It is now confirmed that a small ice cap formed on the Tyndall Plateau and flowed across the Lake Dora area and south along the King Valley as an outlet glacier with numerous small cirque glaciers formed on the peaks of the West Coast Range and flowed east onto the floor of the valley (Fitzsimons *et al.* 1993). Four glacial stages are recognised in the Quaternary of the West Coast, and it is fitting that the Moore Glacial Stage estimated to have occurred between 390,000 and 730,000 yrs. B.P. should be named after T.B. Moore.

ACKNOWLEDGMENTS

Bobbie Bruce, Librarian, Royal Society of Western Australia, kindly provided much useful information. John Carswell and Emeritus Professor Eric A. Colhoun provided information to me, and their thorough reviews significantly improved the paper. Peter Purcell gave useful comments on an early version of the paper.

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(accepted 14 August 2022)

APPENDIX 1

Biographic notes on some persons mentioned in the paper

Edward John Dunn (1844–1937), geologist and mining surveyor, was born near Bristol, England, and emigrated to Victoria with his family in 1849. He was educated at Beechworth, Victoria, and worked for the Geological Survey of Victoria before moving to South Africa in 1871 where he was Government Geologist for the Cape Colony concerned with gold, coal and diamond deposits, glaciated landscapes and geological mapping. He returned to England in 1873, and then came back to Victoria in 1886 to work in private practice. He was appointed Victorian Government Geologist in 1904, a post he held until he retired in 1912. As Government Geologist he published a series of significant reports on Victorian geology and gold deposits and established a geological museum and mining laboratory. He was awarded the Murchison Medal by the Geological Society of London in 1905 and was elected President of the Royal Society of Victoria in 1906.
https://www.eoas.info/biogs/P001070b.htm
https://en.wikipedia.org/wiki/Edward_John_Dunn

Sir Archibald Geikie (1835–1924), one of the most eminent geologists of the late nineteenth and early twentieth centuries was born into a middle-class professional family in Edinburgh in 1835, the eldest of eight children, one of whom was his younger brother James. He graduated from the University of Edinburgh in 1854 and joined the British Geological Survey in 1855 and rapidly rose to prominence. Although at first he had supported the iceberg theory, his views had changed under the influence of Ramsay, and in a classic paper which he read to the Geological Society of Glasgow in 1862 he described the glacial deposits of Scotland in an exhaustive manner (Newbegin & Flett 1917).

He was appointed director of the newly created branch, the Scottish Geological Survey, in 1867. When Murchison founded a chair of geology in 1870 at the University of Edinburgh, Geikie was his choice as professor, and he was appointed the following year. He went on to succeed Sir Andrew Crombie Ramsay as head of the Geological Survey of Great Britain in 1881, a post he held until he retired in 1901.

Geikie's field and research work took him all over the British Isles and to many parts of Europe. He successfully combined his duties to both posts as well as devoting time to private research and writing. As well as his scientific writings, Geikie wrote several well-known biographical and historical books. His autobiography, published in 1924 (Geikie 1924), contained only two references to his younger brother James.

James Geikie (1839–1915) was a graduate of Edinburgh University. While he never entirely came out of his elder brother's shadow, he did achieve academic eminence in his own right and his work on glaciation was particularly important. In 1861 he was appointed Assistant Geologist at the British Geological Survey and in 1867 moved to Scotland becoming District Surveyor in 1869 under his brother. He subsequently succeeded his brother in the post of Murchison Professor of Geology at the University of Edinburgh in 1882.

James accumulated a vast worldwide store of knowledge of the geology of the glacial and interglacial periods of the Ice Age, publishing his findings in *The Great Ice Age* (Geikie 1874). The book was dedicated to his 'teacher and friend' Andrew Crombie Ramsay (pl. 2C, appendix 1) who advised him 'I am delighted to hear of the success of your book, which indeed I never doubted, for I always considered it a first-rate production' (quoted in Newbigin & Flett 1917).

At the beginning of 1889 Geikie was awarded the Murchison Medal of the Geological Society of London, 'in acknowledgment of his important contributions to the geology of North Britain, and especially for his investigation of glacial phenomena'.

Both brothers were made Fellows of the Royal Society: Archibald in 1865 and James in 1875; and both were awarded the Geological Society's Murchison Medal: Archibald in 1881 and James, as stated, in 1889.

Charles Gould (1834–1893), the son of famous naturalists John and Elizabeth Gould, worked at the British Geological Survey under the direction of Sir Roderick Murchison from 1857 to 1859. On the recommendation of Murchison, he was appointed by the Tasmanian Government as Geological Surveyor in 1859. His work took him over much of Tasmania where his geological observations were generally correct. His contract was allowed to lapse in 1869 but he remained in Tasmania until late 1873. Following an 1873 visit to a tin claim he had leased with J.R. Scott he named the nearby Mount Ramsay in honour of his former colleague at the British Geological Survey. Gould travelled widely after leaving Tasmania and died in Montevideo, Uruguay, in December 1899.

Robert Mackenzie Johnston (1843–1918), civil servant, naturalist and statistician, was born near Inverness, Scotland, educated in Glasgow and emigrated to Tasmania in 1870. A man of exceptional ability, he was the government's main financial and economic policy adviser and gained a national reputation as an expert on federal financial matters during the negotiations leading up to Federation. He contributed many papers on palaeontology, geology, zoology and botany in Tasmania but is best known for his monumental *Systematic Account of the Geology of Tasmania* (Johnson 1888). Its treatment of the island's Permian, Triassic and Tertiary rocks and fossils demonstrated outstanding scientific skills and laid firm foundations for the serious study of Tasmanian geology. He died in Hobart in 1918.
(Wettenhall 1983); http://www.utas.edu.au/tasmanian-companion/browse_r_concepts.htm

APPENDIX 1 cont.

Alexander Barr Montgomery (1862–1933) was born in Edinburgh and educated in Dunedin, New Zealand. He graduated from the University of New Zealand in 1881 and joined the New Zealand Public Works Department in 1883 transferring to the New Zealand Mines Department at the end of 1885. In 1889 he was appointed by the Tasmanian Government as Inspector of Mines and Geological Surveyor (Government Geologist), at a time of intense development. At the end of 1896 he returned to New Zealand as superintending engineer to Kauri Gold Estates Limited, which was developing its large freehold property on the Hauraki Peninsula. In August 1902 he was appointed Western Australian Government State Mining Engineer. He retired in 1930 and died in 1933.
https://www.wikitree.com/wiki/Montgomery-8838

Thomas Bather Moore (1850–1919) prospector and explorer, was born at New Norfolk, Van Diemen's Land. After elementary schooling in the Colony, Moore completed his education at Windermere College in the English Lake District under the guardianship of an uncle and returned to Tasmania in 1868. In 1874 Moore commenced his exploration of Tasmania's west coast by examining the area south of Mount Bischoff for tin and gold. He was a heroic figure and the 'last of the true explorers' of western Tasmania (Binks 1980). On 1 January 1877, with his brother James Andrew, he commenced work exploring the route and cutting the overland track from Lake St Clair to Mount Heemskirk. Moore was a competent botanist and geologist, and a founder and life member of the Queensland Branch of the Royal Geographical Society. Moore died on 14 August 1919 at Queenstown and was buried at Strahan (McShane 1986). Moore was elected a Fellow of the Royal Society of Tasmania in June 1885; and was also a Fellow of the Royal Geographical Society (date conferred is not known).

Alexander Morton (1854–1907) was born in New Orleans, USA, in 1854 and died in Hobart in 1907. Widely travelled, he had studied the natural sciences and was appointed Curator of the Royal Society of Tasmania's Museum and Library in Hobart in 1884. In 1885 the Society's museum and gardens were renamed the Tasmanian Museum and Botanical Gardens and incorporated with a board of trustees. Morton was reappointed Curator and Secretary, becoming Director of both the museum and gardens in 1904. He helped to establish the Queen Victoria Museum and Art Gallery at Launceston and acted as Honorary Curator from 1891–96 (Mercer 1986).
https://adb.anu.edu.au/biography/morton-alexander-7666

James Reid Scott (1839–1877) was an explorer and colonial Tasmanian politician, member of the Tasmanian House of Assembly and later the Tasmanian Legislative Council. Scott was born in Scotland and educated as a surveyor, but never practised his profession. He made many exploring expeditions in the western and northeast districts of Tasmania and did valuable work in mapping the Western Highlands. He held the office of Colonial Secretary until 1873 and died suddenly at Hobart on 25 August 1877. He was elected a Fellow of the Royal Society of Tasmania in 1868.
https://en.wikipedia.org/wiki/James_Reid_Scott

Charles Percy Sprent (1849–1887), surveyor was born at Hobart in 1849. In 1871 he was appointed District Surveyor of the North-western District of Tasmania and during the next ten years he did valuable pioneering work in opening the way for prospectors by his explorations of the country lying between Mount Bischoff and Macquarie Harbour. In 1876 he penetrated the mineral belt to the east of the Meredith Range, between Waratah and the Pieman River, cutting a track through a dense tangle of scrub and forest. His explorations did much to assist the opening of the rich mineral resources of Western Tasmania. In 1882 he received the appointment of Deputy-Surveyor-General, in recognition of his services to the Colony. He died at Hobart on 20 June 1887. Sprent had papers published by the Royal Geographical Society of Australasia and the Royal Society of Tasmania.
https://en.wikisource.org/wiki/The_Dictionary_of_Australasian_Biography/Sprent,_Charles_Percy

Sir Andrew Crombie Ramsay (1814–1891) spent much of his early years on the island of Arran off the west coast of Scotland and developed an interest in geology, and met luminaries such as Charles Lyell and Scottish geologist and physicist William Nichol. He was appointed secretary of a committee presenting a geological model of Arran to the 1840 meeting of the British Association for the Advancement of Science held in Glasgow and there met noted geologists George Bellas Greenough, William Buckland, John Phillips, Roderick Impey Murchison, Henry Thomas De la Beche and others, forming some of the most lasting and influential friendships of his life. Murchison recruited him as Assistant Geologist to the British Geological Survey in 1841. He undertook mapping in Wales and was appointed Professor of Geology at University College, London, in 1847. In 1848 he commenced mapping in North Wales and became interested in the glacial geology of Snowdonia, presenting the first public discourse on the former existence of glaciers in Wales to the Geological Society of London in 1849 and publishing his first paper in 1852 (Ramsay 1852). He visited the Alps in August 1852, seeing his first glacier and studying first-hand the effects of glaciers on the landscape.

Ramsay supported the appointment of Murchison to head the British Geological Survey following the death of De La Beche in 1855. In the summer of 1858 Ramsay and John Tyndall made an expedition together into Switzerland for the purpose of studying glaciers and ice-action; they met in the Alps on several subsequent occasions.

Ramsay was elected President of the Geological Society of London in 1862, shortly thereafter giving an address on lake-basins which was in direct contravention of Lyell's work: Lyell and Murchison rejected the study, but Ramsay was supported by 'younger bloods' Charles Darwin, J.D. Hooker, J.B. Jukes and Archibald Geikie (Geikie 1895). On 15 May 1868, Ramsay wrote to Geikie 'I have long

APPENDIX 1 cont.

given up taking any notice of those who oppose me. They are impenetrable, and I feel so sure I am right, that I can well afford to leave the rest to time'. In 1864 Darwin asked Ramsay whether he 'or anyone at Jermyn St' (that is, the British Geological Survey) had written 'to young Gould in Tasmania' about evidence of glaciation in the mountains. He further stated that if he knew Gould's address, he would write himself (letter 4560 www.darwinproject.ac.uk).

Ramsay was appointed Director-General of the British Geological Survey following the death of Murchison in 1871 and retired at the age of 65 in 1881, at which time he was knighted. He was probably the best field geologist of his day and as he became older, he was especially interested in the development of scenery, physiography and of course glaciation. He left a deep mark in the origin and history of British scenery, and in structural geology.

'WILLIAMANE' STYLE AND THE USE OF DYNASTIC LABELS IN THE CLASSIFICATION OF COLONIAL ARCHITECTURE

by Eric Ratcliff

(with thirteen plates)

Ratcliff, E. 2022(i:xii): 'Williamane' style and the use of dynastic labels in the classification of colonial architecture. *Papers and Proceedings of the Royal Society of Tasmania* 156: 57–66. ISSN: 0080–4703. Albion House, 153 & 155 George Street, Launceston, Tasmania 7250, Australia. Email: eric.ratcliff.albion2@gmail.com

It is argued the term 'Williamane', as applied to an architectural style that emerged in the time of transition between the Georgian and Victorian periods in Britain and its colonies commonly referred to as the 'Regency', has particular validity and usefulness in the historiography of colonial architecture in Australia, notably when applied to some Italianate designs by James Blackburn and some of his contemporaries in Tasmania and other colonies. It is suggested that the use of the term might reasonably be extended to another contemporaneous style that is 'Pointed', but neither 'Gothick' nor 'Victorian Gothic'.
Key Words: architectural style, colonial architecture, James Blackburn, Tasmania, Regency, Williamane, Italianate.

The British colony of Van Diemen's Land was established during the historical period of the Regency, and its early development was in the stylistic period in the history of architecture and the decorative arts that has acquired the same name. Between the architectural fashions thus recognised in Britain and those that are clearly 'Victorian', a distinctive Italianate style appeared. The architectural historian Timothy Mowl proposed for this the term 'Williamane', relating it in chronology and character to the short reign (1830–1837) and personality of King William IV. Mowl described the style as:

> *Italianate: round-arched, belvedered and villa-modest in spirit. It was bourgeois in feeling, a sentimental evocation of Italian holidays [...] not of Italian grand tours. Reassuringly Classical in detail, but Romantically towered and galleried in profile, it was a style of modest compromise between two periods of confidence.* Mowl 1987, p. 153

Although this useful label has been available for over three decades, it has not gained wide currency, and the style it represents has received little examination. The term is particularly useful in Tasmania in understanding some works of the prominent colonial architect James Blackburn (1803–1854) and his contemporaries.

I have introduced the unfamiliar term in previous publications without a closely reasoned argument for its utility. A paper on the emergence of the Italianate styles that became so dominant in the Australian colonies in the nineteenth century differentiated between those derived from vernacular sources and those from Italian high style (Ratcliff 2012), and a chapter on a transition from Regency 'Georgian' and on an elaborated Victorian Italianate style recognised the eventual confluence of such influences (Ratcliff 2015a, p. 964). With a particular interest in stylistic transitions, I perceived a need to identify a distinctive style that emerged from the smorgasbord of the Regency and had not become characteristically Victorian, although the evolution occurred quite rapidly in the mainland colonies, where the simpler style had rarely appeared. For Tasmania, the importation of the style was essentially from Britain, although in one case it was probably by way of a publication from the United States of America. Its clearest expression on the Australian mainland was produced in the moment when Melbourne was still an architectural colony of Tasmania, before it became Victorian in two senses of the word, and its brief appearance in New Zealand was due to an architect of Tasmanian birth.

A defence of the term requires a consideration of the notion of style in architecture and the decorative arts, the use of dynastic labels, and the divergent tendencies to 'lump' or 'split' among those who classify natural and human phenomena: taxonomists and art historians. It also requires the recognition of a stylistic Regency, and of the status of transitional forms and features. The besetting problem in the identification of architectural style is that it often involves the taxonomy of the unique, but perceptible similarities will always have heuristic value.

The notion of 'style' is thoroughly embedded in the western European languages: *style, stile, stil,* but it resists definition. *Webster's Dictionary* makes the most creditable attempt, with abstraction of the idea and appropriate recognition of differentiation, change and chronology:

> *...manner or form of execution or presentation of any art or work; characteristic or specific mode of arrangement, construction or development; peculiar choice of forms and mode of treating them, determined according to changes of thought at different times and stages of development. (*Webster 1948, p.252)

The *Shorter Oxford English Dictionary* splits the concept, following its historical method: the current use of the word 'style' in relation to creative writing is dated from

1577, in relation to the visual and other arts from 1706, and specifically to an architectural style from as late as 1770, although it was clearly in the same use long before that (Langley 1742, Warton 1754). Since the eighteenth century, when confused labels such as 'Saxon' and 'Gothic' were applied to medieval buildings in Britain, the notion of style has increasingly been applied in the retrospective classification of architecture. At the outset of a work entitled *The Dilemma of Style,* J. Mordaunt Crook introduces:

> *... style as understood since the Renaissance: a conscious system of design, a visual code based on tectonic preference, a post-vernacular language of forms.* (Crook 1987, p. 13)

In keeping with the theme of his book, Crook is concerned to emphasise the consciousness behind the idea, implying an absence of this and perhaps a limited aesthetic sense in those who built in a vernacular manner. That gloss is particularly inapposite in the colony of Van Diemen's Land/Tasmania, where our common nineteenth-century buildings usually show evidence of a consciousness of style, as the leading expert on vernacular building in England, Robert Brunskill, noticed on a visit to Tasmania (Brunskill 1982). When a free settler or a convict on ticket-of-leave built his dwelling, Jack sought to be as good as his master, in style if not in scale (Ratcliff 2015b).

In Western Europe, the use of dynastic labels has a long prehistory (e.g., in the reign of Henry VI, under Henry III and the three Edwards) (Milner 1800) and became widespread and persistent in Western literature. In Britain, 'Elizabethan', 'Jacobean', 'Queen Anne', 'Georgian' and 'Victorian' are well ingrained, and the last is even accepted in the United States, where, understandably, 'Georgian' is sometimes avoided. 'Edwardian' is also recognised, but in Australia nationalistic sentiment has rapidly substituted the term 'Federation' for the styles that emerged between the late 1880s and the First World War (Saunders 1969, Smith 1969). That last innovation has not been unquestioned (O'Neill 2000, Willis & Goad 2000). In France, 'Carolingian', a succession of 'Louis' styles, XIII to XVI, 'Régence', 'Empire' and 'Restauration' are thoroughly established, referring to changes in fashion that did not exactly coincide with the regimes named; in Portugal, 'Manueline' is well understood.

Such usages carry the risk of confusing date with style but provide a robust and popular shorthand. The alternatives are unsystematic and confusing: eponymous, or related to a prominent exponent (Wrenaissance, Anglo-Jackson, Palladian, Puginian, Soanian); descriptive (Pointed, Cyclopean, Rococo), archaeological (Grecian, Roman, Egyptian), historic (Renaissance, Jacobean), critical (Baroque, Neo-Classical, Revival), satirical (Stockbrokers' Tudor) or exotic (Chinoiserie, Moghul), but most of these are alive and well in detailed discourses.

To argue the validity of the term 'Williamane' it is instructive to consider the emergence of the term 'Regency' to denote a stylistic period, for what is under consideration in this paper may appear as a transition from a transition. The historical Regency in Britain extended from 1811 to 1820, but the influence of the Prince and his designers pre-dated that period, and extended throughout the reign of his brother, and well into that of his niece. Those who recognise the term 'Regency' as a label for a stylistic period are in limited agreement about its extent. Goodhart-Rendel entitled his lively book, based on lectures delivered in 1934, *English Architecture since the Regency,* but his reference was to the historical period and not the present discussion (Goodhart-Rendel 1953). The earliest popular work to adopt the term appears to have been Donald Pilcher's *The Regency Style 1800–1830* (Pilcher 1947). In the remainder of the twentieth century, and in chronological order, the various writers of *The Connoisseur Period Guides* in the 1950s accepted 1810 to 1830 as the stylistic Regency (Edwards & Ramsay 1968), John Harris examined *Regency Furniture Designs 1803–1820* (Harris 1961), David Watkin's volume on Regency buildings adopted the span 1790–1840 (Watkin 1982); Giles Worsley edited *Architectural Drawings of the Regency Period 1790–1837* (Worsley 1961); John Morley wrote *Regency Design 1790–1840* (Morley 1991), Steven Parissien's *Regency Style* spoke of 'the last years of the eighteenth century to 1837' (Parissien 1992), and in Australia, Christopher Menz curated an exhibition and a catalogue, *Regency: British Art and Design 1800–1830* (Menz 1998). It will be noticed that only one of those sources starts with the historical Regency; three of them stopped at the accession of William IV, and two at the accession of Queen Victoria, confusing style with history. Turning to the authoritative dictionaries of architecture, Fleming, Honour and Pevsner have no entry for Regency in their editions from 1966 to 1985 (Fleming *et al.* 1991), and after the death of Nikolaus Pevsner, reluctantly admit the 'modern and imprecise term' in 1991 (Fleming *et al.* 1991); James Stevens Curl gives 'late 1790s' to 1830 (Curl 1999). Arbitrary as the various proposals may be, we might agree on a span from 1790 to 1840 in Britain, very slightly later in Van Diemen's Land after 1803, and recognise that the interval embraces the emergence of the style that can be identified as 'Williamane'.

In Peter Murray's section of *A History of English Architecture* there is a chapter on 'Holland, Soane, and Nash: the Regency' in which he writes of the style that emerged in the last years of the eighteenth century as

> *...an amalgam, but possessing a distinct character of its own, and quite different in intention from the deliberate revivalism of the [...] early and middle years of Victoria's reign.* (Kidson & Murray 1962, p. 252)

Murray recognised the French influence in the emergence of the style through Henry Holland's undoubted francophilia, but more generally, and despite the trouble with Napoleon, Regency style closely paralleled *le Style Empire* across the Channel, with ideas flowing in both directions. The French had undoubted priority in the adoption of Italian rural motifs (pl. 1), and it can be

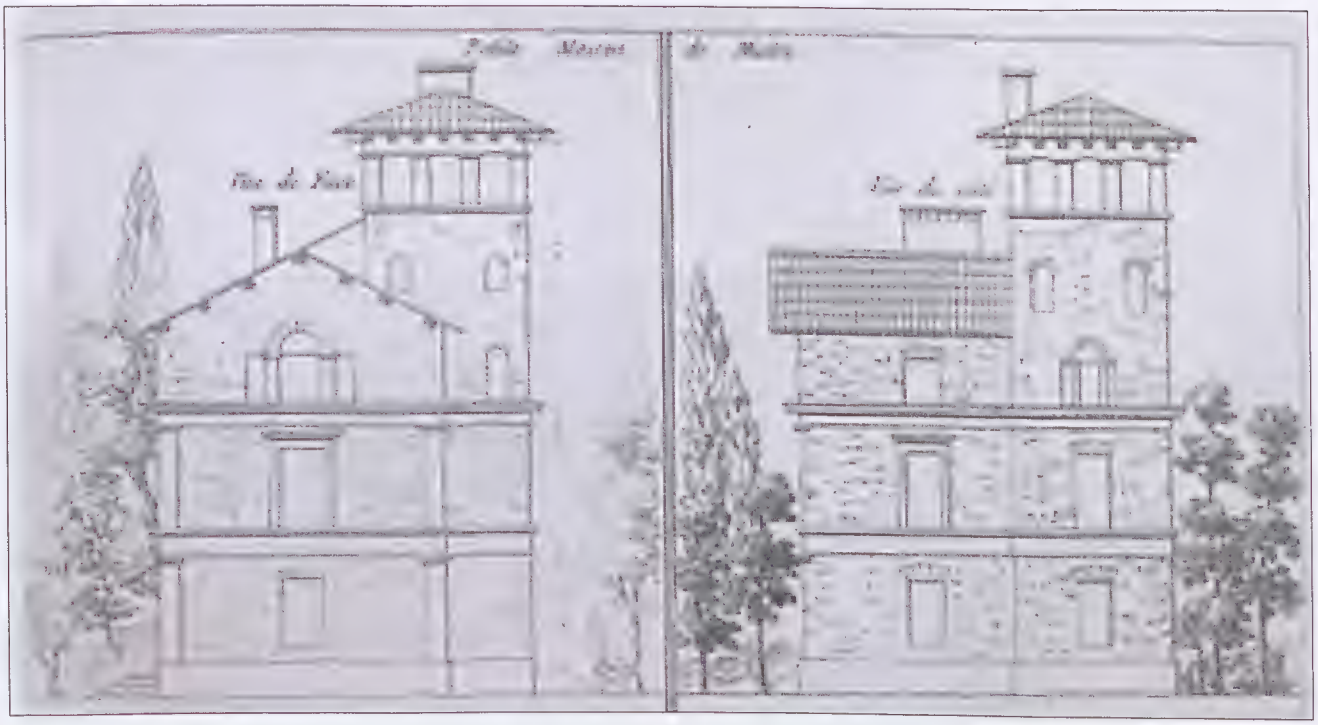

PLATE 1 — Petite Maison de Maitre, a villa à l'italienne, built for the engineer Lomet near Paris, from J.C. Krafft, Recueil d'architecture civile, Crapelet, Paris 1812, Planche XXIV: 'Deux petites mai-sons de campagne, par M. Lamel, adjutant général'.

argued that through that influence, and when he added a campanile to The Deepdene in about 1818, Holland was a progenitor of the Italianate style in England (Morley 1991). The same influence was spread by J.B. Papworth through his publications, including *Rural Residences,* produced that same year (Papworth 1818).

The other importation to Britain of an 'Italian' idea was reported to have been through a painting by Claude Lorrain owned by Earl Ashburnham (now in the Birmingham City Art Gallery) that shows a round-towered house near the Ponte Molle near Rome (Claude 1645). The resemblance is limited, but John Nash is believed to have been inspired by the picture to design 'Cronkill' in Shropshire in 1802, and then a number of other houses in what has been called his 'Cronkill' or 'Claudean' style up to 1815, with plain stucco, wide, consoled eaves and round-headed windows, and again in more of a reversion to Regency Georgian in his Park Villages in London after 1823 (Mansbridge 1991). Nash was losing interest in the Italianate as others brought it into fashion, but he contributed to an acceptance of a greater freedom in form and may be responsible for an occasional elaboration of the eaves on otherwise plain buildings.

Broadly, Regency style implies an antepenultimate development from Late Georgian Neoclassicism, affected by the near-simultaneous emergence of Gothick and Greek Revival in the middle of the eighteenth century, and confounded by the extreme eclecticism and elaboration of such works as the Royal Pavilion at Brighton (Moghul without and Chinoiserie within) or Penrhyn Castle (ponderously neo-Norman), and the elegant simplicity of the style summarised by Osbert Lancaster, briefly sheathing his critical dagger:

> *The numerous villas erected at this time [...] with their delicate ironwork balconies, their ingenious and successful bow-windows, and their coats of sensible and attractive stucco, are among the most charming and original small buildings in the whole history of English architecture.* (Lancaster 1938, p. 52)

It is this more popular manifestation of Regency taste that is of relevance in the consideration of colonial architecture in Tasmania and beyond.

It can be taken that a stylistic Regency period is now widely accepted, but it is also necessary to note that there are relatively recent writers who do not allow the term to stand free of its succession: Doreen Yarwood identifies 'Late Georgian' prior to 1800, and 'Regency and Early Victorian' extending to 1850 (Yarwood 1963), and John Betjeman's popular *Pictorial History of English Architecture* adopted that same linkage (Betjeman 1972). For both, the influence of Italy is represented by the more ornate *palazzo* style of the Pall Mall clubs, and not the rural vernacular that informed our present subject. The style under any label has received limited recognition. 'Villa-modest' Italianate does not appear amongst Doreen Yarwood's thousands of drawings and fell between the bristles of the broad brushes of other writers, unless represented by John Nash's related 'Cronkill' or Park Village style. In his discussion of the dating of the stylistic Regency, Steven Parissien recognised *en passant* Timothy Mowl's proposal of the term, Williamane (Parissien 1992), but at the time of writing, the Wikipedia entry on 'Regency Architecture' was asserting that 'the next reign of William IV from 1830 to 1837 has not been given its own stylistic description', a

statement that is clearly untrue (*Wikipedia* 2021, https://en.wikipedia.org/wiki/Regency_architecture).

It can be argued that the stylistic Regency was a time of transition combined with extreme eclecticism, and that the Italianate style was just one among many. However, from its first appearance it was a fully formed style, and most of its 'transitional' appearances result from the application of some features to earlier buildings, or to new ones of conservative form. An important Tasmanian example of the former is in the Italianate additions after 1850 to 'Stowell' at Battery Point, designed by Francis Butler (1823–1916), freshly arrived from his training in England. Butler had been left to be raised and educated in England and did not re-join his family in the colony until after he had completed his indentures. The Regency house of about 1831 had been acquired by the architect's father and was to become the probable locus of inspiration for Hal Porter's dark play, *The Tower* (Porter 1963).

The French discovery of the Italian vernacular probably resulted from the Napoleonic invasion, and perhaps more specifically from educated visits to Petrarch's villa in the Colli Euganei or Raphael's reputed villa near Rome, the latter known in France from a *tondo* painted by Ingres in 1807. In England, the Late Georgian and Regency periods were a time of accelerating stylistic neophilia, variously explained by the industrial revolution and such innovations as cast iron, the 'grand tour' and the restrictions on it caused by war with France, and boredom with the long Georgian hegemony. Any new and unfamiliar importation was likely to create at least passing interest.

Among the most enduring popular products originating in the Regency is blue-and-white transfer-printed china and earthenware from Staffordshire, and second only to the 'Willow Pattern' in longevity is Spode's 'Blue Italian' pattern, introduced in about 1816 and still in production today (pl. 2). The engraving used to decorate the ware includes all that the untravelled in England at the time might imagine about Italy: Roman ruins, a castle in decay but habitable, and some humbler buildings, one with a low-pitched roof and one with a little tower and arched openings.

In defence of 'Williamane', it is necessary to justify the identification of a distinctive style, although it may depend as much on the more elusive quality of 'character', particularly when such a salient feature as a tower is lacking. The vernacular Italianate aspect of the style, clearly owing much to French precedents, came to Britain in the Regency, and can be seen as a precursor of later fashions, particularly Victorian Italianate, although that was to be more affected by the 'high style' of the later Renaissance *palazzi*, as anglicised by Sir James Barry and others, the kind of Italianate architecture that dominated building in Australasia from the 1860s to the decade before the First World War.

As with all architectural styles, the manifestations of Williamane are various, but the buildings that can be so described will combine at least three of the following features:

PLATE 2 — Spode's 'Blue Italian' pattern (detail) c. 1816, transfer-printed china, W.T. Copeland & Sons c. 1847.

- Where it is not concealed by a parapet, a low-pitched roof, often gabled.
- A square tower like a *campanile*, usually topped with a *belvedere* with a low-pitched pyramidal roof.
- Round-arched openings, typically with plain architraves (not usually moulded as in 'Palazzo Italianate' or Victorian derivatives).
- Window-openings often grouped together, usually in pairs.
- Where there is no parapet, broad overhanging eaves supported by consoles, often paired. Open gables may also have consoles or brackets.
- Asymmetrical massing, with wings on different axes.
- A *loggia*, usually with arched openings.

The style had certain advantages; it was less costly to build than the more elaborate styles emerging at the time, Gothic Revival and neo-Romanesque, and its asymmetry allowed for the same freedom of planning, unlike the Georgian style that was constrained by the demands of symmetry, at least in external appearance.

As with other imported styles, Van Diemen's Land/Tasmania produced few major examples, but its most important colonial exponent, James Blackburn, worked on this island until 1849 and was associated with one important building from the brief time when the Port Philip colony was its architectural province. The two colonial-born architects, William Archer (1820–1874) and William Henry Clayton (1823–1877) both used the style: Archer conspicuously at 'Woolmers' (pl. 3) and Clayton especially after he emigrated to New Zealand. Consequently, the idea of Williamane can be defended from the vantage point of a former British colony.

The importation of style to the colony occurred in several ways, most of them clearly illustrated by the coming of the Williamane fashion: firstly, through the arrival of architects who had become aware of it in Britain, before their emigration or transportation, or in the case of the two colonial lads, during their training in England, and secondly through the influence of published designs imported to the colony.

PLATE 3 — The garden front added by William Archer to his father's house at 'Woolmers' near Longford in about 1842, possibly the earliest example of an Italianate style in Australia. Remnant Georgian in the quoins, Williamane in the flattened gables, the small tower, and the hints of campanili in the chimneys.

PLATE 4 — Design from John Lee Archer's office for old St John's Church at Ross, completed in 1838 and demolished in 1868 because of foundation failure. (Tasmanian Archives, Open Access Item No CSO1/1/935)

The Colonial Engineer and Architect, John Lee Archer (1791–1852), in office from 1827 to 1838, was associated with at least two buildings with Williamane features, but it cannot be certain that they were his designs because of the likely candidates working in his drawing office. The original church at Ross, completed in 1838 had a square tower with a low-pitched pyramidal roof and round-headed openings (pl. 4), and the old schoolhouse at Richmond, begun in 1834, has a low-pitched gable and a round-headed window, both unusual for the time.

The transported architect, James Blackburn, was to become the most important Williamane designer in the Antipodes, although, like most of his colleagues, he worked in a variety of styles. He was trained as an architect, engineer and surveyor, and worked in London for the Commissioners for Sewers for Holborn and Finsbury, while privately engaging in speculative building. This resulted in financial difficulty, and he forged a cheque in the name of his employers and was sentenced to transportation for life. From the time of his arrival in Van Diemen's Land, he was employed in the Department of Roads and Bridges, and the Colonial Architect's office, and earned a conditional pardon in 1836 and a free pardon in 1841 (Preston 1966). After that he practised as an architect and engineer in loose partnership with another ex-convict, James Thomson (1805–1860), a Scot who brought *inter alia* a species of Edinburgh Georgian to the colony. Blackburn's buildings reflect many influences characteristic of his time: Gothick, Doric Revival, Neo-Romanesque, Rundbogenstil, Pall Mall Palazzo, and cottage Regency, but his most distinctive style was Williamane. The most accessible examples are both at New Town, Hobart, where he lived until 1846: 'The Tower' that gave its name to Tower Road (pl. 5), and the former Independent (Congregational) Chapel (pl. 6). The latter is the more evidently Italianate of the two, with its *campanile* dominating a hillside as if in Tuscany, but its details include Scots *margins* at the corners and openings with surrounds of Blackburn's devising, like those of the raked arcade sheltering the gallery stair, adapted from Blackburn's plagiarised Neo-Romanesque design for St Mark's Church, Pontville, begun in 1839. 'The Tower' has its character changed by the castellated parapet above a boldly coved cornice of Egyptianate derivation, both now much affected by spalling of the stonework.

Blackburn had access to architectural books imported to the colony by Lady Jane Franklin, the wife of the Governor, Sir John, the Arctic explorer. Lady Jane subscribed to London papers like *The Civil Engineer and Architect's Journal,* from which Blackburn derived the peculiar design for St Mark's Church (Ferrey 1838, Broadbent 1981), and was clearly avid for ideas from any source that he could apply in a busy colonial practice. His additions to 'Rosedale' in the Campbell Town district clearly owed much to an engraving of John Nash's 'Cronkill', and his design for Holy Trinity Church in Launceston (pl. 7) appears to have been considerably plagiarised from Henry Goodridge's design brought to the colony by Bishop Polding and used for St John's Church at Richmond (pl. 8) (Macfie 1995, Ratcliff 2013). The former was clearly Anglo-Italianate in influence, but the latter belongs to a style to be briefly examined below.

James Broadbent and Miles Lewis have both located Blackburn's work at the time of transition when 'expression' and 'style' became 'the preoccupation of many Early Victorian architects' (Broadbent 1981, p. 33) and 'a change of taste in about the 1830's meant a swing from Greek to Italian' but neither of them found a term to identify a transitional Italianate style. Phillip Cox and Clive Lucas confound confusion, calling the New Town Congregational chapel 'Italian Romanesque' (Cox & Lucas 1978, pp. 195, 196). While praising Blackburn with faint damns, Broadbent attributed to him 'the most distinctive, if not

PLATE 5 — 'The Tower', New Town, Hobart, designed by James Blackburn in about 1840, is a Williamane pile conjoined to a timber-clad Regency cottage; the architect's own residence is immediately next door. Note the paired arched windows, Scottish margins, Egyptianate cornice and the castellated parapet concealing a flat roof.

PLATE 6 — Former Congregational Chapel, New Town, Hobart, designed by James Blackburn and built in 1842. An Italianate campanile is placed asymmetrically before a round-arched preaching-house with a low-pitched roof (Libraries Tasmania Open Access NS165-1-205).

PLATE 7 — The original Holy Trinity Church, Launceston, built in 1841–1842, was designed by James Blackburn. The octangular turrets and pinnacles were probably suggested by Goodridge's design, and four were intended, but the contractor, Joseph Moir, economised at the liturgically eastward end. Photograph by William Cawston c. 1866. (LINC Tasmania Open Access LPIC22-1-33)

PLATE 8 — St John's Catholic Church at Richmond, built in 1836 to a design by Henry Goodridge, shown in its original form in a detail from an undated drawing of the town by Thomas Chapman. (RST Art Collection)

PLATE 9 — One of the towerless Italianate houses in the suburb on Bathwick Hill, Bath, Somerset that was called 'England's Florence'. A design by Henry Goodridge circa 1840, photographed during the Second World War by R.F. Wills for the National Buildings Record.

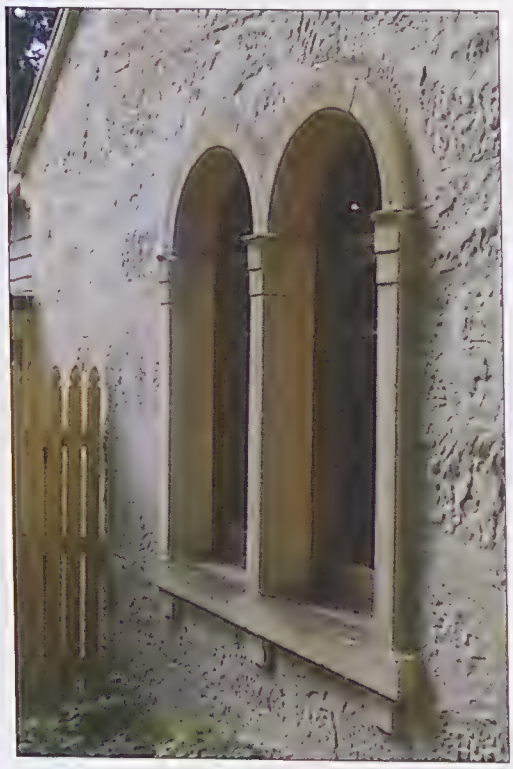

PLATE 10 — Window detail of the cottage in the Royal Botanical Gardens, Hobart, built for the Secretary of the Royal Society of Tasmania in 1845, designed by William Porden Kay the Colonial Architect. It is now known as 'The Friends' Cottage'.

the most distinguished, range of buildings of any colonial architect', and further concluded that:

> *He is rarely original and occasionally incompetent, but he is one of the most ingenious and interesting architects practicing in early colonial Australia, and from his work we can gauge attitudes and influences which are frequently difficult to assess in those of greater stature.* Broadbent 1981, p. 37

Henry Edmund Goodridge (1797–1864) had earned a prominent place in the brief history of Williamane architecture when he became William Beckford's professional collaborator in the building of his Lansdown Tower near Bath, and later when he designed some less unique Italianate houses, some with towers, creating what was described as a 'England's Florence' on the other side of that city (Little 1947, pl. 9). The church at Richmond was the result of one of his attempts at a serious Pointed style that was not yet 'Gothic Revival', and which I will argue to be best regarded as a species of Pointed Williamane (pl. 8).

Two young men of colonial birth who grew up on the Norfolk Plains near Longford, and were sent to Europe for their architectural education, trained in an era of stylistic variety, and returned with some Williamane ideas in their heads, if not their pattern books. William Archer from 'Woolmers' added a uniquely Italianate garden front to his father's house (pl. 3) and later designed the largest country house in Australia for his cousin: 'Mona Vale' at Ross (also known as the Calendar House) is in an Italianate style that owes more to Sir James Barry's 'Palazzo Italianate' and to Queen Victoria and Prince Albert's towered 'Osborne House' than to the plainer Williamane. William Henry Clayton applied some Williamane features in Tasmania, but the first important building he designed after his move to New Zealand was much more typical of the style.

The Franklins' nephew who became Colonial Architect of Van Diemen's Land, William Porden Kay (1809–1897), is best known for the Tudor Gothic of Government House and the Wilmot monument in St David's Park in Hobart, but the design his office produced for the cottage in the Botanical Gardens, built in 1845 to accommodate the secretary of the Royal Society, is a small hybrid with emphatically Williamane windows (pl. 10). As in the case of John Lee Archer, it cannot be certain that a design emanating from the Colonial Architect's office is by the official who signed the drawings.

The Williamane Italianate fashion produced other discernible effects in Tasmania from early in the 1830s, such as the curious flattening of the roof of Captain Matthew Curling Friend's cottage, 'Newnham Lodge', and some symmetrical houses that appear to have been struggling to escape the colonial Georgian under wide consoled eaves: Isaac Sherwin's 'Alice Place' in Launceston, and the Reverend H.P. Fry's rectory, 'Ellerslie' overlooking the Montpelier Road in Hobart since about 1850.

Imported through France, the transliterated Italianate of the British world became for a time something of an international style. Following his visit to Britain in 1826 (Aslet 1987), the Prussian, Karl Friedrich Schinkel, who had

PLATE 11 — 'Northbury', Longford, Tasmania, designed by Horace Bennett in 1862, almost certainly after an engraving in Andrew Jackson Downing's Cottage Residences, borrowed from the Launceston Mechanics' Institute library, and not returned.

PLATE 12 — 'Scone' near Perth, Tasmania, designed by Harry Conway (c.1829–1905), built in 1870, enlarged in 1882–1884, including the tower, designed by Percy Oakden (1844–1917), in the 1920s. (Known as Eskleigh Memorial Home, Perth.) (Tasmanian Archives Open Access _LPIC147-5-329_)

visited Italy as early as 1805 without evident effect on his work, soon applied it to the 'Roman Baths' at Charlottenhof Castle at Potsdam (Steffens 2003). Schinkel is most often associated with the Grecian Revival style in Prussia, but he also developed an unhappy Germanic Gothic expressed in the Freidrichswerder Kirche in Berlin, designed in 1827 (Bonet 2003, pp. 53, 60, 61). In Prussia, he displayed the same mitigated eclecticism that characterises the work of such architects as Goodridge and Blackburn.

A well-known British exposition of the Italianate fashion was James Parker's *Villa Rustica*, first published in two volumes in 1832 and 1833 and then as an expanded second edition in 1847 (Parker 1847). Parker's designs do not represent the emergence of the fashion, but arguably a commercial response to it. Although presented as based on Italian examples, the text makes clear that they are Parker's derivations; most of the plates show a unity of style that can only be attributed to the author, and some characteristic elaborations that would be recognisable if they had ever appeared in Tasmania. The most derivative Tasmanian example had a different source.

The Italianate fashion, naturalised in Britain, flowered in America well into the nineteenth century through the pattern books of Andrew Jackson Downing, Gervaise Wheeler and Samuel Sloan, with a progressive loss of innocence as their details succumbed to the eclectic elaboration that we associate with high Victorian architecture (Downing 1850, Sloan 1852, Wheeler 1867). Downing's published designs in particular appear to have renewed the use of the style in Britain, and had direct influence in Tasmania, when Horace Bennett (fl. 1859–62), a transient architect of dubious reputation, used a plate from his *Cottage Residences* to design 'Northbury' at Longford (Neale 2011) (pl. 11).

In the Australian colonies, the towered house followed a more rapid evolution into a high Victorian Italianate of the kind that Mark Girouard called 'mini-Osbornes', referring to the influence of the marine villa on the Isle of Wight that Thomas Cubitt designed with Prince Albert (Girouard 1979). 'Scone' (now 'Eskleigh Memorial Home') is an accessible Tasmanian example (pl. 12), less florid than its 'Boom style' sisters across Bass Strait.

Timothy Mowl limited his identification of a Williamane style to the 'villa-modest' Italianate, but the time and the motivation of that style was clearly contaminated by another influence, producing a transitional Gothic that was no longer Gothick but not yet Gothic Revival. This can be seen as a Pointed equivalent of the style identified by Mowl, and Henry Goodridge was one of its notable exponents (pl. 8), but far from being alone in this. While the Italianate adopted the compositional freedom of asymmetry, which had been one of the advantages of Gothick, the transitional Gothic frequently returned to the constraints of symmetry. This 'Pointed Williamane' style is arguably the parent of a species of dispirited Gothic that can be found in thousands of minor churches and chapels raised throughout the Anglophone world during the ensuing century. They are more likely to be of brick and stucco than of stone, to have pointed openings with little or no tracery, and perfunctory buttresses standing in for pilaster strips. Many share the flattened roof-pitch of their Italianate cousins, and if funds permitted, a few pinnacles appeared to symbolise their reach towards Heaven such as these two churches in Launceston (pls 7, 13). They are sometimes pretty, but more often appear banal, and are little regarded as they are demolished or converted to secular use, but in my view the earlier examples are as clear a product of the time surrounding the reign of William IV as the style to which Professor Mowl has drawn our attention.

PLATE 13 — St Andrew's Presbyterian Church, Launceston, designed by William Henry Clayton (1823–1877) and opened in 1850. (Tasmanian Archives Open Access_PH30-1-16)

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(accepted 8 June 2022)

THE VALE OF BELVOIR, NW TASMANIA – OVERVIEW OF GEOLOGY, GEOMORPHOLOGY, VEGETATION AND HUMAN HISTORY

by Keith D. Corbett and Elizabeth (Sib) Corbett

(with two text-figures and ten plates)

Corbett, K.D. & Corbett, E. 2022 (i:xii). The Vale of Belvoir, NW Tasmania – overview of geology, geomorphology, vegetation and human history. *Papers and Proceedings of the Royal Society of Tasmania* 156: 67–79. ISSN: 0080–4703. 35 Pillinger Drive, Fern Tree, Tasmania 7054, Australia. (KDC*, EC). *Author for correspondence. Email: keith.corbett@bigpond.com

The Vale of Belvoir is a large open grassy valley of striking appearance located northwest of Cradle Mountain. At 800 m altitude, it is Tasmania's only subalpine limestone valley. The unusual geology and human history have combined to give the valley its unique character. The three main geological elements are: the folded Ordovician limestone bedrock, which produced the synclinal valley and numerous sink holes; lava flows of Cenozoic basalt, which have covered parts of the valley floor; and Pleistocene glaciations, which have delivered large amounts of bouldery till to mantle much of the valley floor and redistribute much of the basalt into the glacial deposits to add to the fertility of the soils. The glacial deposits have disrupted the drainage of the valley, so that the Lea River and Lake Lea now drain northwards out of the valley, while the Vale River drains most of the valley and flows southwards to the Pieman system. Dolerite erratics in the glacials indicate that the ice came from the Cradle Mountain area.

The Vale has one of the most extensive and diverse areas of montane grassland in the state and contains several threatened vegetation communities and plant species. The valley provided Tasmanian Aboriginal people with abundant wildlife and shelter, and their burning practices maintained its grassy nature and remnant patches of rainforest. Europeans arrived in the 1820s and grazed cattle from the 1850s onwards; their practice of patch burning the grasslands has been continued by the current owners, the Tasmanian Land Conservancy.

Key Words: Vale of Belvoir, Tasmania, geology, geomorphology, vegetation, glacial history, human history, Aboriginal burning.

INTRODUCTION

The Vale of Belvoir is a large open limestone-floored valley located about 15 km NNW of Cradle Mountain, between the Black Bluff Range to the west and Bonds Range to the east (fig. 1). It is about 10 km long and 2 km wide, and trends northeast–southwest. It is crossed by the Belvoir Road and a power transmission line, but no other major infrastructure or permanent habitation exists. The valley has an open grassy floor flanked by patches of rainforest and eucalypt forest (pl. 1). The shallow Lake Lea lies near the northern end of the valley, and drains northwards via the Lea River, while the main part of the valley drains southwards via the Vale River.

There are many unusual and important aspects to the valley, including its geology, geomorphology, human history, vegetation and fauna. It was probably an important place for the first Tasmanians for many thousands of years, and Europeans have summer-grazed cattle on the native grasses at 'the Vale' for over 150 years. The Tasmanian Land Conservancy (TLC) purchased the freehold grazing leases (476 ha) in the centre of the valley in 2008, and grazing has continued while research has been conducted on its effects.

While not covered here, the Vale also has a diverse fauna community including several state and nationally listed threatened species, and apparently Thylacine *Thylacinus cynocephalus* were once common (Charleston 2008). A comprehensive list of fauna is contained in the BushBlitz 2010 report (https://tasland.org.au/reserves/vale-of-belvoir-reserve/). The TLC has a strong program of research and monitoring of the natural values of the Vale including the impacts of cattle grazing and invasive species (Tasmanian Land Conservancy 2013, 2017, 2019).

The authors have explored the valley numerous times and have updated the geology as previously mapped (Barton *et al.* 1966, Pemberton & Vicary 1988, Vicary & Pemberton 1988), mainly by establishing that much of what had been shown as basalt is glacial till rich in basalt boulders (fig.1). This paper is partly based on an earlier article in the *Tasmanian Naturalist* (Corbett 2012).

Physiography and drainage

The floor of the valley is mainly undulating to flat, with sink holes scattered throughout. A low hill of basalt, Daisy Hill (fig. 1), extends across the eastern half of the valley in the central part, and a smaller hill about 1.5 km to the southwest of this is also capped with basalt. The northern end of the valley is defined by several larger basalt hills to the north of Lake Lea. The valley narrows to the south, and disappears at the Fourways (fig. 1), where the Vale River is joined by two tributaries (Speeler and Fleece creeks) and turns abruptly southwest.

Drainage of the valley is unusual and involves two rivers, one flowing north and the other south. The Lea River

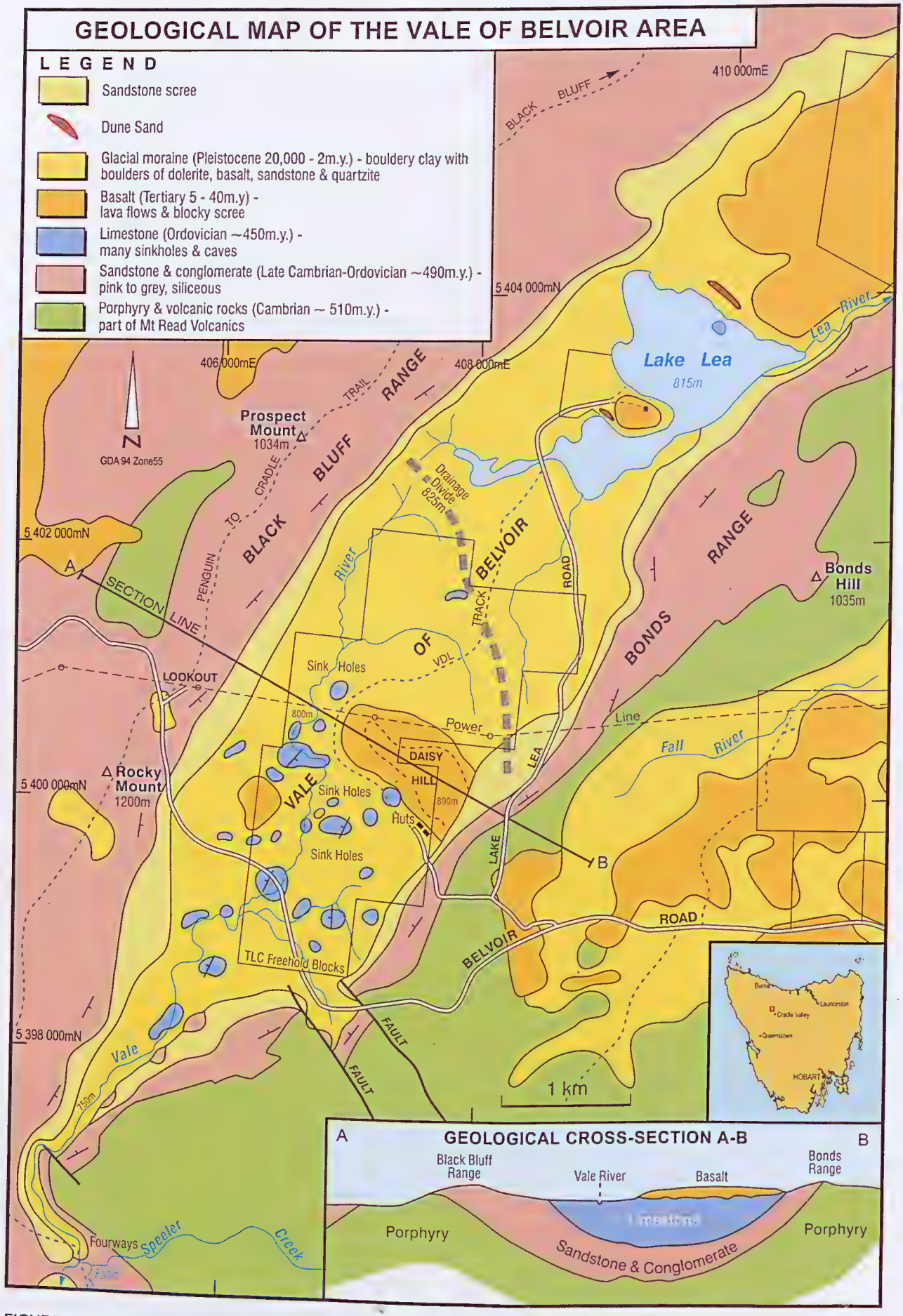

FIGURE 1 — Geological map of the Vale of Belvoir area. Modified after Pemberton & Vicary (1988) and Vicary & Pemberton (1988).

drains from the northeast corner of Lake Lea, and flows northeast through a narrow gorge, joining the Iris and then the Wilmot (via Lake Gairdner) and eventually the Forth to debouch into Bass Strait. A broad low (10 m) rise in glacial till just south of Lake Lea Lagoon separates this system from the headwater streams of the Vale River, which flows south on a meandering course through the main part of the valley. The Vale River exits the southern end of the valley via a waterfall, then flows southwest through a 5-km-long sandstone gorge, over the 25-m Reynolds Falls, before joining with the Fury River to flow into the head of Lake Mackintosh – and eventually via the Pieman River to the Southern Ocean.

The opposing drainage system is the result of the deposition of Pleistocene till, particularly in the area just south of Lake Lea. The lake was probably formed at this stage also, although there may have been an earlier lake formed because of the basalt flows in the Cenozoic.

GEOLOGY

The geology of the valley was first mapped by Threader (1963), in a survey to determine the limestone resources present. This work was part of the regional mapping of the Mackintosh Sheet (1:63 360 scale) for the Geological Survey in the 1960s (Barton *et al.* 1966, Collins *et al.* 1981). The area was mapped in more detail (1:25 000 scale) as part of the Mt Read Volcanics Project within the Geological Survey in the 1980s (Pemberton & Vicary 1988, Vicary & Pemberton 1988, Pemberton *et al.* 1991).

The three basic geological components are: (i) the *Pleistocene glacial deposits*, which cover most of the floor of the valley; (ii) the *Cenozoic basalt*, which forms Daisy Hill and the smaller hill to the southwest and is abundant in the glacial deposits in many areas; and (iii) the *Ordovician limestone*, which underlies the valley and is the primary reason for its existence (fig. 1).

A sandstone and conglomerate sequence, pink to grey in colour, underlies the limestone, and crops out extensively along the Black Bluff Range and Bonds Range. This sequence is an extension of the siliceous rocks, known generally as the Owen Conglomerate or Owen Group, which form the West Coast Range (Corbett *et al.* 2014), although with more sandstone. The sequence becomes thinner to the east on Bonds Range, where it mostly consists of a distinctive grey sandstone with abundant worm burrows known as the Moina Sandstone (Pemberton *et al.* 1991). The Moina Formation is of Middle Ordovician age (~470 Ma), whereas the underlying pink sandstone-conglomerate sequence exposed on Black Bluff Range to the west is part of the Upper Owen Sandstone and of Late Cambrian age (~490 Ma, Pemberton *et al.* 1991, Corbett *et al.* 2014).

Cambrian volcanic rocks belonging to the widespread Mt Read Volcanics succession underlie the sandstone-conglomerate and are exposed in several 'windows' on Black Bluff Range, and on the eastern slopes of Bonds Range. The sequence in the latter area consists mostly of

PLATE 1 — View north from Daisy Hill to Lake Lea, showing summer flowering of daisies (Orange Everlastings and white Grassland Paperdaisy) and rainforest on valley margin.

PLATE 2 — Vale River flowing through limestone outcrops and riverine sedgeland, looking south.

PLATE 3 — Sink hole in glacial moraine north of Daisy Hill.

a large intrusive body of quartz-feldspar porphyry known as the Bonds Range Porphyry (Pemberton *et al.* 1991).

Ordovician limestone

The Ordovician limestone (about 450 Ma) is the same 'Gordon Limestone' which forms most of the other large limestone valleys in Tasmania, for example at Mole Creek, Gunns Plains and the Florentine Valley. However, unlike the Vale, these are all lowland valleys at around 400 m altitude. The limestone is a grey, hard rock which is seen as scattered low knolls of outcrop, and as smaller outcrops along creeks and in sink holes (pl. 2). Bedding is usually visible and solution features are abundant, presumably formed when the land surface was at a higher level. Fossil worm tubes are seen on a few bedding planes, but fossils are otherwise uncommon. Chert nodules are present in the limestone outcrops on the north side of the small basalt hill on the western side of the Vale River.

The presence of a limestone substrate is clearly indicated by the hundreds of sink holes across the valley floor. These are typically 10 to 20 m across, with grassy to muddy walls and floor where the surface material – soil or till or basalt boulders mostly – has collapsed into the top of the cave beneath. Many contain wombat burrows indicating the very large population of these mammals in the valley (Tasmanian Land Conservancy 2013). Some sinkholes have exposed limestone sides, and others have permanent ponds or small lakes in them. Those on the valley floor north of Daisy Hill tend to be larger, up to 40 m across, and some have semi-permanent water (pl. 3). Sink holes within basalt scree persist up the slopes of the basalt hills in some areas. Some caves are known at deeper levels in the limestone but are generally difficult of access (Tasmanian Land Conservancy 2013).

The limestone and sandstone–conglomerate units (and the underlying volcanic rocks) have been folded into a broad *syncline* or elongate basin, which forms the valley, with *anticlines* of the siliceous rocks rising on either side to form the Black Bluff Range and Bonds Range (fig. 1 cross-section). The keel of the syncline is evident to the south, where the valley narrows to the point, at the Fourways, where only the rocks underlying the limestone are present at surface. Bedding in the limestone dips westward along the eastern and central parts of the valley, forming the eastern flank of the syncline, and gently eastward along the western side. A strong sub-vertical cleavage is evident in the few western outcrops, suggesting the possibility of a major fault along the western side of the fold, which occurred during the middle Devonian Tabberabberan Orogeny (360–390 Ma) (Seymour 1980, Corbett 2019).

Cenozoic basalt

Cenozoic basalt flows (10–50 Ma) have buried part of the irregular limestone surface on the valley floor. The basalt flows form the 100-m-high dome-shaped Daisy Hill in the middle part of the valley, the smaller hill to the southwest, a small round knoll of outcrop between these two, and the larger hills at the northern end (fig. 1).

The basalt on Daisy Hill is about 60 m thick, although the base is obscured. The rock is hard, dark grey and fine-grained. The eruptive source is not known, but the shape of the hill suggests the flow(s) may have come from the southeast, outside the valley, where there is abundant other basalt, and flowed down the slope into the valley. The small hill of basalt to the southwest, and the very small (5 m across) outcrop to its northeast, appear to be remnants of a (thin?) flow which has mostly been removed by glacial erosion. The small outcrop has sub-horizontal columnar jointing, indicating cooling from the side. This suggests the basalt may have flowed into, and cooled within, a subcircular depression, such as a sink hole. The overlying part of the flow must have been removed by ice.

Pleistocene glacial deposits

Pleistocene glacial deposits (20 ka–2 Ma) cover most of the valley as an irregular superficial layer ranging in thickness from about 1 m to over 6 m. It is evident in most places as a scattering of erratic boulders of different kinds on the surface and is seen in many sink holes and creek banks as a mixture of boulders and smaller clasts in a clayey matrix (pl. 3). Some of the boulders are over 3 m in diameter and can only have been carried there by ice. The dominant rock type making up the boulders varies from place to place. Basalt is the most common (pl. 4), but there are areas where dolerite (pl. 5), grey Moina sandstone, pink pebbly sandstone and fine conglomerate, volcanic rock types from the Mt Read Volcanics, and irregular ironstone material are dominant.

The thickest morainal deposit appears to be in the area between Daisy Hill and the lagoon of Lake Lea, particularly west of the Van Diemen's Land (VDL) Company track, where a broad low rise of morainal material forms the divide between the north-flowing and south-flowing drainage (fig 1). Basalt boulders are prominent over much of this rise (pl. 4). A similar low rise forms the divide east of the VDL track, but dolerite and sandstone are the dominant boulder types in this area (pl. 5). These surface boulders do not show any clear weathering rinds, but exposures in a creek bank 40 m west of the track in this area show completely decomposed basalt clasts up to 10 cm in diameter (pl. 6), suggesting at least some of the moraine is relatively old (Kiernan 1990).

The widespread and abundant basalt boulders in the till indicate that a considerable amount of the original flow has been eroded and re-distributed by glacial ice flowing across the valley. This erosion appears to have been greatest in the area to the south and west of Daisy Hill, where there are numerous low rounded outcrops of limestone and just a couple of remnants of the original basalt lava flow(s) (fig. 1). The area to the east and north of Daisy Hill, by contrast, has been one of glacial deposition, and the only limestone seen in this area was in several adjacent sink holes beneath a cover of till. This may indicate that some of the ice flowing northwest across the southern part of the valley has been deflected northwards around Daisy Hill.

PLATE 4 — Abundant basalt erratics in glacial moraine, with *Diplarrena* rushland, about 1 km north of Daisy Hill. This area was previously mapped as basalt.

PLATE 5 — Large dolerite erratics in glacial moraine 800 m north of Daisy Hill, looking NW across the valley.

PLATE 6 — Deeply weathered clasts of basalt in glacial moraine, creek bed 1 km north of Daisy Hill.

Blocks of ironstone, or ferricrete, up to several m long lie on the surface of the moraine just south of Lake Lea. They appear to be derived from an area in the northern part of the valley where similar ironstone is exposed in cuttings on the Lake Lea Road. These outcrops suggest that the ferricrete may have been developed on a section of the original limestone sequence which has been deeply weathered and oxidised (possibly during the Cenozoic), rather than being within the glacial deposits. This may explain the pre-Pliocene magnetic age for the ferricrete obtained by Augustinus and Idnurm (1993), in attempting to date the glacial deposits, and the uncertain U/Th dates on the ferricretes recorded by Augustinus *et al.* (1997).

The presence of dolerite in the moraine indicates that the main direction of ice flow has been from the Cradle Mountain area to the southeast – the nearest upslope source of dolerite (as previously inferred by Derbyshire 1968), and that ice has flowed over the lower part of the Bonds Range and diagonally across the valley. Small patches of boulder moraine are found on top of the Black Bluff Range (including along the Belvoir Road near the lookout), indicating that some of the ice flowed out of the valley and over the range to the west. Most of the deposition, however, appears to have been in the valley. Several possible end moraines, in the form of low northeast trending ridges rich in basalt and pink sandstone clasts, were noted against the bottom of the slope just southwest of the Lake Lea Lagoon. These suggest that ice may have piled up against the bottom of the slope in this area.

Other superficial deposits

Two small areas of clean coarse sand have been mapped near Lake Lea (fig. 1) and appear to be remnants of former dunes (Pemberton & Vicary 1988, Vicary & Pemberton 1988). The larger one is approximately 100 m north of the northern shore of the lake, and is vegetated, about 1.5 m high and 100 m long. The smaller one is located on the southern side of the basalt isthmus on the western side of the lake and is not as well preserved. Their location on the north side of stretches of open water suggests a relationship to a prevailing southerly wind, and they probably record a period of wind erosion (deflation) in the late Pleistocene, similar to the Pleistocene dune features seen in many parts of inland and coastal Tasmania (Colhoun 2014). Lake Lea itself, however, is thought to be mainly due to damming by glacial deposits and possibly basalt.

A thin layer of sandstone scree is present along the foot of the slope of the ranges on both sides of the valley and appears to overlie the glacial deposits. Small areas of alluvial sand and silt are present along the Vale River and in places around Lake Lea but have not been separately mapped.

We have not examined the soils in the Vale of Belvoir, but it is likely that most are derived from glacial deposits and would be influenced by the composition of the till – particularly the presence of abundant basalt. Actual alkaline limestone soils could be mainly restricted to streamside areas and limestone outcrops lacking the glacial cover.

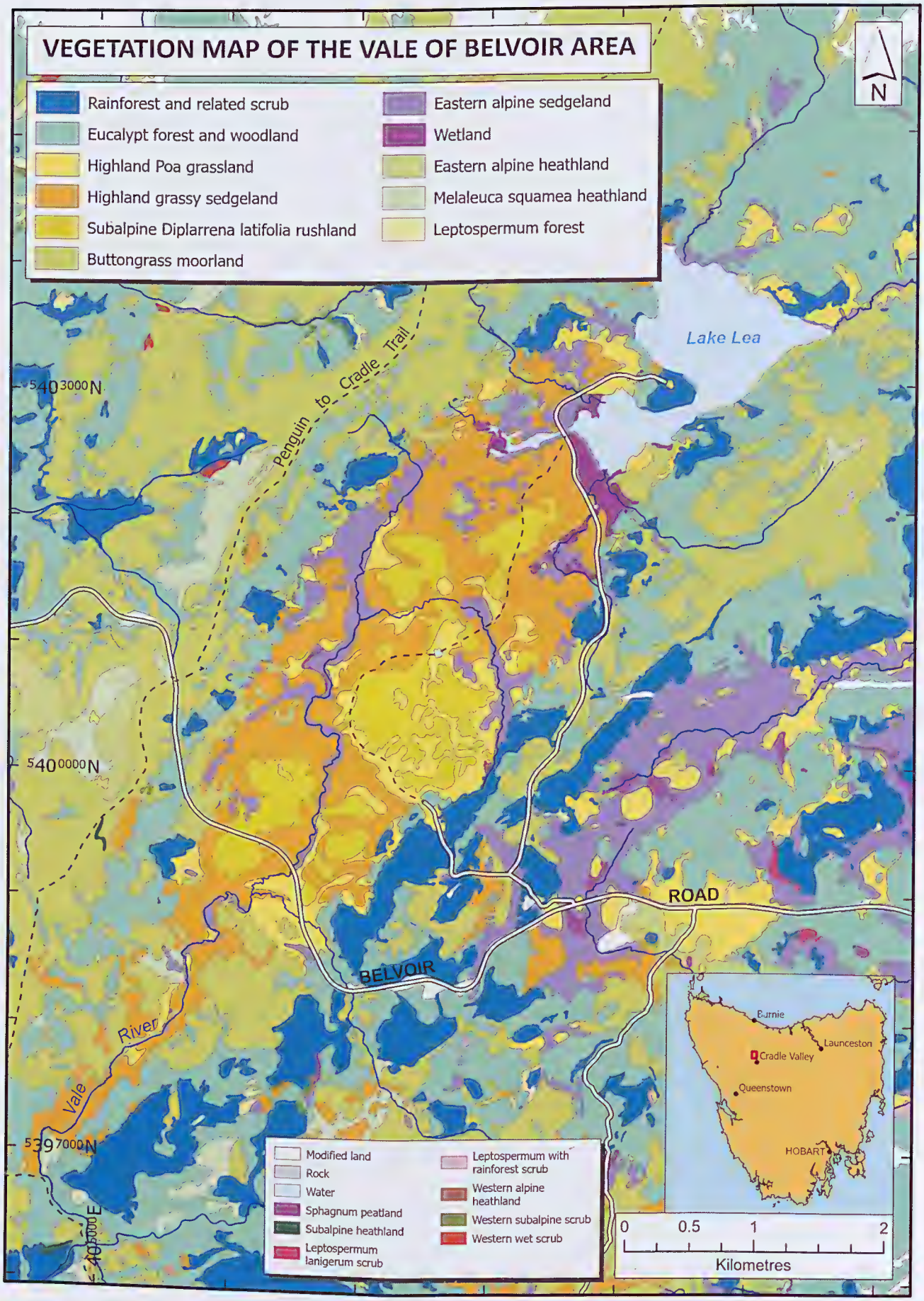

FIGURE 2 — Vegetation map of Vale of Belvoir area. Prepared from TASVEG LIVE data by L. Mitchell for the authors. Original TASVEG mapping by Sib Corbett.

VEGETATION

The Vale of Belvoir is one of the most extensive and intact highland grassland ecosystems in Tasmania, with exceptional floristic diversity compared to other Tasmanian highland grasslands (Tasmanian Land Conservancy 2013). It includes considerable areas of threatened and rare communities and at least eight rare and threatened plant species, in addition to many spectacular flowering plants. The grassy communities occur mostly on the treeless valley floor, extending over approximately 10^2 km (fig. 2). Narrow patches of rainforest and eucalypt forest border the grasslands on the sides of the valley, merging into buttongrass and heathy to scrubby moorland on the slopes and tops of the ranges. Buttongrass is also present in parts of the valley (pl. 7).

The Vale provides perhaps the most spectacular flowering of mountain daisies anywhere in Tasmania, mostly due to the swathes of Orange Everlastings *Xerochrysum subundulatum*, which blaze across the valley floor and on Daisy Hill in late January–February (pl. 1). In places these are mixed with sweeps of the rare white Grassland Paperdaisy, *Leucochrysum albicans* ssp. *tricolor*.

Over 12 vegetation communities occur at the Vale (TASVEG 4 and TASVEG Live mapping), of which five are listed as threatened under the Tasmanian *Nature Conservation Act 2002* (Tasmanian Land Conservancy 2013; CR Dickson, pers. comm. 2022). Three of the threatened communities, Highland Poa Grassland, Highland Sedgy Grassland, and Subalpine *Diplarrena latifolia* Rushland, (fig. 2), are concentrated in the central part of the valley between Lake Lea and Belvoir Road.

Vegetation communities

The Highland Poa Grassland is dominated by *Poa labillardierei* Silver Tussockgrass and *Poa gunnii* Gunns Snowgrass, with other grass and sedge species and some important inter-tussock herbs such as *Stylidium graminifolium*, *Viola hederacea*, *Gentianella diemensis* and *Euphrasia collina*. This grassland community is best developed around the Daisy Hill area (pl. 7), where it inter-grades with *Diplarrena* rushland.

The Highland grassy sedgeland is the most abundant vegetation community and is best developed in the lower parts of the valley floor, particularly in the north around the Lake Lea Lagoon (pl. 8). It is dominated by the sedges *Lepidosperma filiforme* and *Carex gaudichaudiana*, with the rush species *Baloskian australe* and *Eurychorda complanata*, plus *Poa* spp and *Gleichenia alpina* (Alpine Coral Fern).

Subalpine *Diplarrena latifolia* rushland is dominated by the white-flowering Western Flag-iris *Diplarrena latifolia* and appears to favour the slightly higher and better-drained areas of the valley floor. There may also be a preference for areas with more basalt in the substrate, such as around Daisy Hill (pl. 7), the basalt hill to the southwest of this, and the basalt-rich areas of moraine to the northwest (fig. 2, pl. 4). Grasses, Mountain Rocket *Bellendena montana* and other small flowering plants can be present between the tussocks.

Wetland is another threatened community and occurs mainly around the southern shores of Lake Lea and as small patches along the Vale River. *Lepidosperma*, *Carex* and *Baloskian* are typical, with thickets of *Richea scoparia* in places. There is a close spatial relationship to the Eastern Alpine Sedgeland, which forms strips along the river (pl. 2) and some of the creeks in places. A few small patches of Alpine sphagnum bog are present on some drainage lines, but too small to be seen on figure 2.

Nothofagus-Atherosperma rainforest occurs as patches along the valley sides and at Lake Lea, with sharp boundaries to the adjacent grassy areas in many places. These cool, shaded forests are typically open callidendrous, with mixed-age Myrtle *Nothofagus cunninghamii*, including some ancient trees. The forests provide cover for the many marsupials which graze the valley, and their distribution suggests they could be remnant patches after long-continued Aboriginal burning.

Eucalypt forest and woodland tends to alternate with the rainforest patches along the valley sides, and in places forms a fringe to the rainforest. Included within this type are patches of *Eucalyptus gunnii* woodland of significant conservation value. Important understorey species include Mountain Pepper *Tasmannia lanceolata*, Mountain Currant *Coprosma nitida*, and Cheesewood *Pittosporum bicolor*.

Threatened plant species

Of the rare and endangered plant species present, the most spectacular are the Nationally Endangered daisy *Leucochrysum albicans* ssp. *tricolor* Grassland Paperdaisy, with its white flowers and pink bracts (pl. 9), and the similar rare *Rhodanthe anthemoides* Chamomile Sunray. Recent surveys indicate that the former has its largest population in the state at Daisy Hill, while the latter typically grows on limestone banks, including along the Vale River. Other rare plants include: *Stackhousia pulvinaris* Alpine Candles, a small, matted herb with star-like white flowers – quite different from the familiar upright candles – mostly found growing around the upper clayey slopes of sinkholes (pl. 10). This species was thought to be restricted to the Vale of Belvoir, and nearby Speeler Plains, but has recently also been found on the Central Plateau (James Wood pers. comm.); *Muehlenbeckia axillaris* Matted Lignum, another small groundcover with fleshy leaves and white flowers, which favours rocky sites; *Viola cunninghamii* Alpine Violet; *Argyrotegium poliochlorum* Greygreen Cottonleaf; and *Scleranthus brockiei* Mountain Knawel. A rare leek orchid *Prasophyllum tadgellianum* is also present.

COMMENTS ON ABORIGINAL HISTORY

Aboriginal bark shelters were seen in the Vale by VDL cattle drovers in the 1820s, and there is even a record of an Aboriginal bark drawing in one of these shelters of a bullock dray which had recently passed by (Haygarth 1998). Several Aboriginal rock artefacts have been found and registered by the authors in a rainforest patch on the western side of the valley.

PLATE 7 — View south from Daisy Hill showing dense *Diplarrena* rushland in foreground, cattle grazing of *Poa* grassland below, rounded outcrops of limestone, golden buttongrass further south.

PLATE 8 — Grassy sedgeland, sedgeland and wetland around Lake Lea Lagoon, looking northeast.

PLATE 9 — Grassland Paperdaisy *Leucochrysum albicans* ssp. *tricolor* at the Vale.

PLATE 10 — Alpine Candles *Stackhousia pulvinaris* from sink hole at Vale of Belvoir. Large leaves are *Velleia montana*.

However, the patches of rainforest along the edges of the valley (fig. 2, pl.1, pl. 5) appear to be remnants of a more extensive forest which likely covered more of the valley but has been reduced to remnants by long-continued burning – presumably by Aboriginal people. The patches are typically surrounded by eucalypt forest, scrub or buttongrass vegetation which is clearly related to fires. Some recent fires have followed these burnt leads from the valley floor up the slopes of the range. There are no apparent geological, edaphic or drainage factors specific to the present rainforest areas, and suitable conditions for rainforest, in the form of reasonably fertile soils (on glacial till for the most part) and moderate to good drainage, occur over a large part of the valley floor. We know that Aboriginal burning was carried out in many places in western Tasmania to encourage grass growth for wildlife (e.g., Jones 1969, Reid *et al.* 1999, Gammage 2012), and that burning of rainforest in areas of such fertile basaltic soils can result in the direct establishment of native grasses (Ellis 1985). Clearing of the rainforest and its replacement by grassland would have been a long process, and while Aboriginal burning seems the likely explanation, it may not be the only cause.

EUROPEAN HISTORY

The Vale of Belvoir was named in 1827 by Joseph Fossey, after the well-known valley of that name in Leicestershire, England. Fossey was on a surveying expedition for the VDL Company, looking for a stock route from Mole Creek to their holdings at Surrey Hills, south of Burnie. The route delineated by Fossey and Henry Hellyer, the other VDL surveyor, was via the Middlesex Plains and Vale of Belvoir, thence over the Black Bluff Range towards St Valentines Peak. The route became known as the 'Western Road' or 'VDL Road', and was used to drive cattle herds, and for general access, for about 30 years. It followed an earlier Aboriginal track, also sited to take advantage of the open country south of the belt of dense forests, with large unbridged rivers, which then extended to the north coast (Haygarth 1998). A rough 4wd track which runs down the valley is still known as the 'VDL track' (fig. 1).

Cattle were summer grazed in the area from about the 1850s, firstly by the Field family, then by George Moon (who built the first hut camp at the Vale in the 1880s), then by the Williams family from Narrawa, near Wilmot. George Williams also ran a summer dairy herd and operated a cheese factory at the Vale in about the period 1915–1935. The discarded whey from the cheese-making was apparently very popular with the local thylacines and tiger snakes! (Haygarth 1998, Charleston 2008). Another unusual venture in the area was by a Canadian, Percy Davis, who purchased land for farming at Lake Lea in the 1890s and tried (unsuccessfully) to grow wheat in ploughed ground near the southern shore.

The Charleston family from Wilmot took over the grazing leases from the Williams through the 1960s, and continued the general grazing practices, including mosaic burning of the grasslands in September to October, for between 100–300 cattle, including calves. A small house and stables, located in a sheltered side valley on the eastern side of the Vale, were established in about 1975. The annual cattle drive with horses from Wilmot and back were memorable events for the family (Charleston 2008). The family sold the 473 ha Vale property to the Tasmanian Land Conservancy in 2008, retaining the right to continue summer grazing as part of the agreement (Tasmanian Land Conservancy 2013).

Initial research conducted by TLC and the Parks and Wildlife Service on the impact of grazing and burning on the grasslands showed that the practices were generally beneficial to biodiversity, in part by maintaining the openness between the tussocks which allows the smaller flowering plants to thrive. Further research has shown that burning is the most important factor on species richness, with grazing having a smaller influence (Leonard & Kingdom 2017, Tasmanian Land Conservancy 2017). This fact, combined with some negative aspects, such as trampling of wetlands, led to a decision to review the grazing activity in 2018. The area around the freehold blocks is now incorporated into the Vale of Belvoir Conservation Area, established in 2000, managed by PWS (Tasmanian Land Conservancy 2013).

Prospectors have searched the Vale and surrounding areas for gold and other minerals since the mid-1800s, with several small mines established on the slopes of the Black Bluff Range further north (Haygarth 1998). Surviving remnants at the Vale from this time include a 100-m-long trench dug through glacial moraine in rainforest on the eastern side of the valley 1.5 km south of Daisy Hill, and a small adit just west of the Charleston's house.

CONCLUSIONS

The striking appearance of the Vale of Belvoir, with its treeless grassy floor bordered by rainforest and eucalypt forest, is the result of its unusual geology and human history. The valley was originally formed by solution weathering of the limestone, and this accounts for the mosaic of sink holes. Basalt flowed into the valley in the Cenozoic and may have covered much of the floor. Much of this was then removed by glacial ice in the Pleistocene, and re-distributed through the valley. The ice flowed out from the Cradle Mountain area multiple times and diagonally across the valley. Maximum deposition was in the area just south of Lake Lea, forming a low divide and causing the bi-directional drainage. The presence of abundant basalt in the glacial deposits may have 'sweetened' the soil and encouraged the development of native grasses when burning of the valley was carried out by Tasmanian Aborigines over a long period. This seems the most likely explanation for the remnant patches of rainforest. European graziers have continued the practice of patch-burning the grasses to maintain the botanical diversity and appearance of this special place.

ACKNOWLEDGEMENTS

The authors acknowledge the cooperation and help provided by the Tasmanian Land Conservancy in providing information, allowing access to the Vale, and encouraging participation in field days and other activities related to the Vale. Particular thanks are extended to Cath Dickson and Sally Bryant for comments on the paper. We thank Felicity Hargraves and Lindsay Mitchell from the TASVEG team for their great help in producing the vegetation map, and Gillian Bennett for drafting the geological map. Grant Dixon and an anonymous reviewer are thanked for their reviews of the paper. All photos used are from the Corbett family collection.

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(accepted 29 September 2022)

VARIATION IN PERCEPTIONS OF THE AESTHETICS OF NEW SUBURBAN DEVELOPMENTS

by Mingming Ma and Jamie B. Kirkpatrick

(with two text-figures and six tables)

Ma, M. & Kirkpatrick, J.B. 2022 (i:xii) Variation in perceptions of the aesthetics of new suburban developments. *Papers and Proceedings of the Royal Society of Tasmania* 156: 81–87. ISSN 0080-4703. School of Geography, Planning, and Spatial Sciences, University of Tasmania, Private Bag 78, Hobart, Tasmania 7001, Australia. (MM, JBK*). *Author for correspondence. Email: j.kirkpatrick@utas.edu.au

Although the nature and correlates of variability in perceptions of the visual aesthetics of rural and natural landscapes have been well-studied, more work is needed on suburban landscapes, particularly to establish the desirable visual aesthetic qualities of new suburban developments. Visual elicitation was used to determine the aesthetic responses of adults of varying place of residence, occupation, gender and age to landscape-scale attributes of new suburban developments. A questionnaire was answered by a global sample of respondents who gave their sociodemographic details and ranked their preferences for different aesthetic attributes of suburban development. Australians and professionals were more likely than other nationalities and blue-collar workers to select the bottom of the hill, rather than the top of the hill. Professionals and those over 44 years old preferred naturalistic suburban boundaries rather than the geometric boundaries preferred by young white-collar workers. Younger respondents preferred one style of house in the suburb compared to three or more styles preferred by older respondents. Most respondents preferred low-density housing. House colour preferences varied by nationality, occupation, age and gender. These preferences may help planners to adjust the attributes of new suburban developments to cater for different subsets of people. Collaborative planning with local people will be necessary to maximise the aesthetic utility of new suburban developments.

Key Words: aesthetics, age, gender, nationality, occupation, suburb design.

INTRODUCTION

> *The marketing of suburbs as a dreamscape, characterised by single family dwellings, spacious gardens, clean air, aesthetically pleasing surrounds, a strong sense of privacy, safety and achievement, and accessibility dates back to the garden city movement.* (Maginn & Anasker 2022, p. 8)

In a substantial contemporary book devoted to suburban 'dreamscapes and nightmares', the above quote contains the only reference to aesthetics or beauty. Since the 1960s, when McHarg (1969) motivated and guided suburban design with nature, there has been limited work on the aesthetics of suburbs as landscapes (Weller 2008, Hein *et al.* 2010) and the aesthetics of suburban blocks (e.g., Nassauer 1993). In contrast, there has been more interest in landscape-scale aesthetic values in the literature, particularly related to natural area and rural planning (e.g., Brooks & Lavigne 1985, Nassauer 1988, Porteous 1996, Mendel & Kirkpatrick 1999). The expansion of suburbia has been inexorable (Bruegmann 2005, Johnson 2006), calling more than ever for aesthetic design, with or without nature.

Aesthetics is not beauty but rather the pleasure derived from the contemplation of landscape (Appleton 1975). Our collective unconscious values prospect from a refuge (Jung 1959, Bourassa 1988). Kaplan and Kaplan (1982, 1989) establish that a view of water through trees from a cave is inherent in humans. They also found, as Bourassa (1988) suggested and Nassauer (1988) and many others demonstrated, that experience can modify this preference.

Function and profitability have ruled suburban planning, with biotic conservation values causing occasional spatial avoidance. We are unaware of any direct influence of suburb-scale aesthetics in the planning process for new developments, apart from some Australian attempts to maintain natural skylines. There is a case for the aesthetics of view fields as a key to happiness (Goldberg *et al.* 2012), as with the garden movement (Freestone 1989, Mackay 2015) and assertions of the undesirability of realised ugliness (Boyd 1960).

The remarkable constancy through time and space of aesthetic perceptions of natural landscapes visited by tourists (e.g., Mendel & Kirkpatrick 1999) may apply to some aspects of the visual aesthetic impact of new suburbs. Alternatively, given the lack of any absolute definition of aesthetics (Bourassa 1988, Hein *et al.* 2010), perceptions of the aesthetics of suburban development may vary according to the tastes of different sociocultural and demographic groups. Such a heterogeneity in perceptions of beauty seems to apply to suburban gardens, which are diverse in composition and structure, with this variation being closely related to sociodemographic characteristics (Kirkpatrick *et al.* 2007). Similarly, different occupational groups have opposite perceptions of the aesthetics of rural landscape change in the Netherlands (van den Berg *et al.* 1998).

The first stage of any incorporation of landscape visual aesthetics into the planning of new suburban developments

is to determine those visual attributes that contribute towards a positive aesthetic experience in the eyes of most beholders, and those that are associated with subsets of beholders or for which there is no agreement.

In this paper, visual elicitation is used to determine the aesthetic responses of adults of varying place of residence, occupation, gender and age to landscape-scale attributes of new suburban developments. We undertake this task as a small contribution to the community and collaborative planning necessary to ensure aesthetic justice (Mattila 2002). Aesthetic justice intersects the right course of action with art. An egalitarian planning justice that transcends aesthetics (Corner 1997, Harvey 2005) could result in an unjust imposition of ugliness.

METHODS

Ethics approval for this project was obtained from the Tasmania Social Sciences Human Research Ethics Committee (EC00336) at the University of Tasmania. Potential respondents were recruited through online web pages. An eventual 203 respondents were informed of the survey by the advertisements or notifications on social media sites. A link on the advertisement sheet accessed the Survey Monkey questionnaire. At this point, respondents read the information sheet and consent page before agreeing to attempt the questionnaire. The consent process required respondents to declare that they were over 18 years old.

Ranking questions using Likert scales and pictorial elicitation predominated in the questionnaire. In anthropology and sociology, visual methods have been widely used to explain and understand images. Pictorial elicitation uses pictures or visual media to build knowledge and data (Smith & Woodward 1998, Glaw *et al.* 2017). This approach allows respondents to understand the questions quickly and effectively and may be more motivating than normal questions. We used digitally created images (c.f. Kuper 2017).

The first four questions asked for information on residence, occupation, gender and age. Questions Q6 to Q11 asked respondents to rank their preferences for different aesthetic attributes of suburban development with other attributes held constant in visual depictions (fig. 1).

Chi-square was used to determine the significance of variation from a random distribution between qualitative variables. ANOVA was used to determine whether the ranking of colour classes varied in themselves and between socio-demographic classes. Fisher's individual error rate was used to determine if classes varied from one another at $P < 0.05$.

RESULTS

Relationships between predictor variables

The only significant relationships between predictor variables were between place of residence and both occupation and gender (table 1). Professional employment was highest among Australian residents. Blue-collar and white-collar occupations were highest among Asian residents (table 1). Females outnumbered males among Australian and Asian respondents, while the reverse pertained to European and other respondents (table 1).

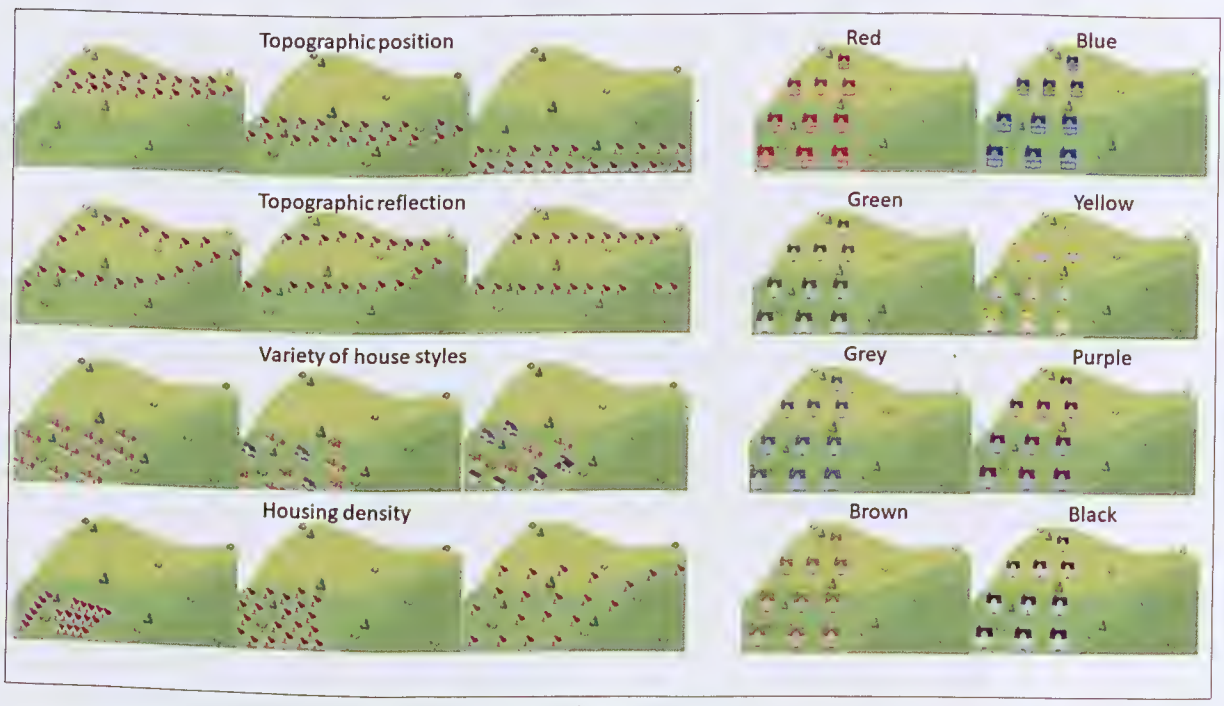

FIG. 1 — Illustrations used in the questionnaire to assess predictor variables.

TABLE 1 — Occupation and gender by place of residence

	Place of residence				
	Asia	Aust.	Europe	Other	P
Occupation:					
Blue-collar	26	12	18	**53**	
Professional	36	**64**	**47**	13	
White-collar	**38**	25	35	33	<0.001
Gender:					
Female	**58**	**62**	44	21	
Male	43	38	**56**	**79**	0.019

Figures are column percentages for each of the two sub tables. The P values are from Chi-square on each of the tables. Bold indicates the highest value in a column within a sub table.

TABLE 2 — First preference for topographic position by predictor variables

	Topographic position		
	Top of hill	Middle of hill	Bottom of hill
Place of residence:			
Asia	40.48	35.71	23.81
Australia	*30.71*	36.72	**32.81**
Europe	**64.71**	*17.65*	17.65
Other	53.33	**40.00**	*6.67*
All	37.31	35.15	27.72
P	**0.000**	**0.020**	**0.009**
Occupation:			
Blue-collar	**52.94**	35.29	*11.76*
Professional	*28.57*	33.33	**38.38**
White-collar	47.27	34.55	18.18
All	38.50	34.04	27.66
P	**0.025**	0.923	**0.006**
Gender:			
Female	34.51	37.17	2.32
Male	40.96	33.33	26.19
All	37.24	35.53	27.41
P	0.357	0.687	0.694
Age (years):			
18-24	36.36	40.91	22.73
25-34	36.08	39.80	24.49
35-44	43.18	20.45	36.36
> 44	34.21	36.84	28.95
All	37.31	35.15	27.72
P	0.176	0.295	0.579

P values are from Chi-square for preferences in each class of the variable. Figures are row percentages. Highest percentages for classes shown in bold, lowest in italics where there is significant variation.

Topographic position of houses

The top of the hill was favoured most by people from all places of residence except Australia, where a middle position was marginally more popular, but the difference in overall preference was not striking (table 2). Australian residents were the most likely to choose a position at the bottom of the hill (table 2). Blue-collar workers were most likely to choose the top of the hill, while professionals were most likely of any occupational class to select the bottom (table 2). There were no effects of gender or age on any of the topographic position variables (table 2).

Reflection of topography

Over half the respondents preferred suburbs that reflected topography, while a quarter preferred a geometric arrangement (table 3). Those who preferred the geometric arrangement tended to be white-collar workers in the 25–34-year age class (table 3). Those who least preferred this shape tended to be professionals and older than 44 years (table 3). There were no effects of gender or place of residence on preferences (table 3).

Style mixture

Approximately one-third of the respondents gave first preference to each of the three options of one, three or five styles (table 4). There was no variation by socio-demographic variables, apart from the strong tendency of younger respondents to choose one style as their first preference (table 4).

Housing density

The aesthetics of medium- or low-density housing were preferred by almost all respondents more than high-density housing (table 5). The European residents had the lowest percentage in preference for medium density and the highest percentage in the low-density class (table 5). Australians had the lowest percentage of first preferences in the high-density class, while others and Australians were high in the medium-density class (table 5). There was no effect of occupation, gender or age (table 5).

House colour

On average, the sequence of colour preference from most preferred to least preferred was green, blue, grey, red, yellow, purple, brown, black (table 6). There was strong differentiation of colour preferences with green more popular than all other colours, blue more popular than all except green, yellow, grey and red being more popular than purple, brown and black, and purple and brown being more popular than black (table 6) (ANOVA, $F = 70.24_{7,1601}$, $P < 0.001$). Opinions were most divergent with red, yellow and brown (fig. 2).

Green was preferred by professionals more than blue- or white-collar workers (table 6). Blue was preferred by

TABLE 3 — First preference for reflection of topography by predictor variables

	Topographic reflection		
	Strong	Intermediate	None
Place of residence:			
Asia	52.38	23.81	23.81
Australia	55.47	21.88	22.66
Europe	64.71	5.88	29.41
Other	60.00	13.33	26.67
All	55.94	20.30	23.76
P	0.891	0.462	0.579
Occupation:			
Blue-collar	58.82	20.59	20.59
Professional	60.61	23.23	*16.16*
White-collar	43.64	18.18	**38.18**
All	55.32	21.28	23.40
P	0.167	0.924	**0.043**
Gender:			
Female	55.75	19.47	24.78
Male	59.92	19.05	21.43
All	57.36	19.29	23.35
P	0.745	0.704	0.265
Age (years):			
18-24	68.18	18.18	13.64
25-34	53.06	15.31	**31.63**
35-44	52.27	27.27	20.45
> 44	60.53	26.32	*13.16*
All	55.94	20.30	23.76
P	0.709	0.375	**0.043**

P values are from Chi-square for preferences in each class of the variable. Figures are row percentages. Highest percentages for topographic reflection classes shown in bold, lowest in italics where there is significant variation.

TABLE 4 — First preference for house style mix by predictor variables

	House style		
	One style	Three styles	Five styles
Place of residence:			
Asia	28.57	29.27	42.86
Australia	35.43	26.56	38.10
Europe	41.18	47.06	11.76
Other	20.00	46.67	33.33
All	33.33	30.35	36.50
P	0.357	0.192	0.221
Occupation:			
Blue-collar	44.12	27.27	29.41
Professional	28.57	33.33	37.76
White-collar	30.91	30.91	38.89
All	32.09	31.55	36.56
P	0.397	0.748	0.799
Gender:			
Female	33.93	26.55	39.64
Male	33.33	36.14	30.95
All	33.67	30.61	35.90
P	0.954	0.083	0.193
Age (years):			
18-24	**40.91**	27.27	31.82
25-34	40.82	26.80	33.33
35-44	27.91	27.27	43.18
> 44	15.79	44.74	39.47
All	33.33	30.35	36.50
P	**0.010**	0.200	0.130

P values are from Chi-square for preferences in each class of the variable. Highest percentages for classes shown in bold, lowest in italics where there is significant variation.

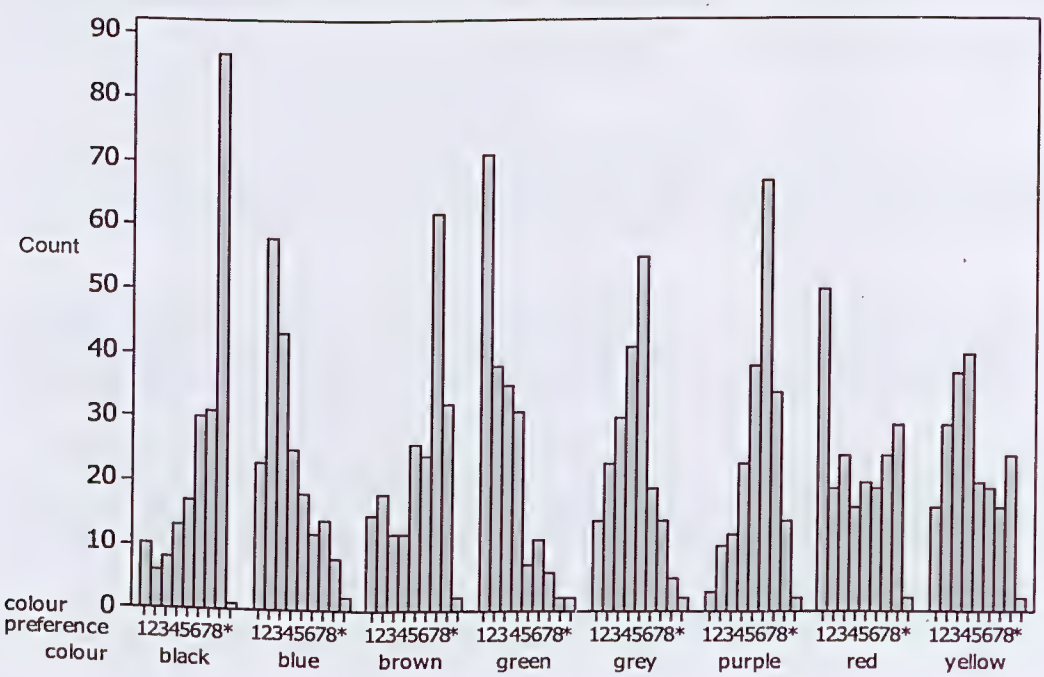

FIG. 2 — Count of preferences for house colours by colour. (1 = most preferred colour, * missing answers)

TABLE 5 — First preference for housing density by predictor variables

	Housing density		
	High	Medium	Low
Place of residence:			
Asia	9.52	34.15	57.14
Australia	14.84	42.19	42.97
Europe	17.65	*5.88*	**76.47**
Other	6.67	**46.67**	46.67
All	13.37	37.81	49.01
P	0.124	**0.025**	**0.018**
Occupation:			
Blue-collar	14.71	33.33	52.94
Professional	14.14	44.44	41.41
White-collar	9.09	27.27	63.64
All	12.77	37.43	50.00
P	0.622	0.245	0.090
Gender:			
Female	14.16	35.40	50.44
Male	13.10	42.17	54.24
All	13.71	38.27	48.22
P	0.950	0.397	0.635
Age (years):			
18-24	13.64	31.82	54.55
25-34	12.24	36.08	52.04
35-44	18.18	38.64	43.18
> 44	10.53	44.74	44.74
All	13.37	37.81	49.01
P	0.949	0.343	0.725

P values are from Chi-square for preferences in each class of the variable. Highest percentages for classes shown in bold, lowest in italics where there is significant variation.

Australian residents to a greater degree than all other residence classes (table 6). It was also preferred more by males than females (table 6). Grey was most preferred by Australian residents and least preferred by European residents and others (table 6). Yellow was most preferred by Asian residents and least preferred by Australian residents (table 6). Brown was more preferred by Australian residents than by Asian and European residents (table 6). It was also more preferred by the 25–34 and > 44-year age groups than the 35–44 age group. The mean rankings of red, purple and black were not significantly differentiated by any of the sociodemographic variables (table 6).

DISCUSSION

There were some points of aesthetic agreement. Most respondents liked the shape of the topography to be reflected in the development and most thought that high-density development was aesthetically inferior to low- and medium-density development. Opinions were almost equally distributed between the three alternatives for the position of the development on a hill and for the degree of mixture of house styles. However, more weight was placed on relationships between preferences and sociodemographic variables than on the overall results, as our voluntary sample is unlikely to be representative of the global population. Relative preferences for red, grey, purple and black houses were the only attributes not to vary significantly with any of our four sociodemographic variables.

The high levels of selection of the bottom of the hill by Australian residents and professionals may partially reflect the high proportion of professionals among Australian residents (table 1). However, the residential location was likely to be more important, as the mean rating for bottom of the hill was highly similar for Australian white-collar and professional workers.

The strong aesthetic valuing of the top of the hill by European residents compared to Asian and Australian residents may reflect the placement of settlements on elevated, non-arable, defensible sites in Europe in the war-torn Middle Ages. In Australia, which forms the other extreme in placement preference, practical considerations, such as the provision of reticulated water and sewerage systems may have made hilltop development rare. An Indigenous society in which proximity to the coast, water and low elevation influenced the location of activity (Jones *et al.* 2019) may also have contributed to the lack of aesthetic appeal of hilltop development. Australian residents are in the green urbanism mainstream (Beatley & Newman 2012). Green urbanists value a natural skyline, rather than one that is built up. Thus, there are skyline preservation guidelines in many Australian planning schemes. For instance, the Tasmania Planning Scheme *22.4.4 Landscape Protection Performance Criteria P2.1* (Tasmanian Government 2017, p. 226) requires prevention of visual impact from building on the skyline. Many local government areas in Australia have planning regulations that were designed to prevent skyline development (e.g., Nillumbik Shire Council 2020).

The association of white-collar workers and 25–34-year-olds with a preference for geometrically shaped suburban developments may reflect a bureaucratic mindset, valuing efficiency. In a similar expression of class preferences, university degree holders, who tend to be professionals, are associated with less regimented garden styles than non-degree holders in Hobart, Tasmania (Kirkpatrick *et al.* 2007).

The greater preference of younger respondents than older respondents for one house style in a development indicates a generational shift in taste. It is interesting that the European residents perceive low-density developments to be their first preference more than Australian residents, given that Australians tend to live in less dense settlements than Europeans.

The high diversity of individual valuation of the aesthetics of colour, with all colours attracting at least some ratings at both extremes, and red, yellow and brown being particularly polarising, makes colour regulation difficult. However, preferences are strongly related to place of residence, and

TABLE 6 – Mean preference for house colour by predictor variables

Predictor	n	Red	Blue	Green	Yellow	Grey	Purple	Brown	Black
Overall mean	201	4.2C	3.4D	2.7E	4.3C	4.2C	5.4B	5.5B	6.3A
Place of residence:									
Asia	41	4.1	3.1B	2.9	3.5B	4.4AB	5.5	6.0A	6.4
Australia	128	4.2	3.8A	2.6	4.7A	3.9B	5.3	5.1B	6.4
Europe	17	3.3	2.4B	2.9	3.8AB	4.9A	5.8	6.3A	6.6
Other	15	4.7	2.7B	2.3	4.1AB	5.1A	5.7	6.0AB	5.3
P		0.421	**0.007**	0.535	**0.010**	**0.011**	0.570	**0.032**	0.260
Occupation:									
Blue-collar	33	3.9	2.8	3.0A	4.26	4.4	5.7	5.7	5.7
Professional	99	4.5	3.5	2.3B	4.40	4,1	5.5	5.2	6.4
White-collar	55	3.6	3.4	3.1A	4.00	4.2	5.3	5.8	6.5
P		0.106	0.145	**0.007**	0.311	0.621	0.540	0.283	0.123
Gender:									
Female	113	3.9	3.8A	2.6	4.3	4.2	5.4	5.3	6.5
Male	83	4.5	3.0B	2.7	4.3	4.1	5.5	5.7	6.0
P		0.131	**0.007**	0.771	0.968	0.803	0.607	0.149	0.126
Age (years):									
18-24	22	4.3	3.5	2.8	4.1	3.9	5.5	5.5AB	6.3
25-34	97	4.1	3.6	2.7	4.4	4.2	5.6	5.4B	6.1
35-44	44	3.8	3.0	2.9	3.9	4.5	5.2	6.2A	6.5
>44	38	4.8	3.6	2.3	4.6	4.0	5.3	4.7B	6.7
P		0.335	0.440	0.519	0.448	0.490	0.604	**0.020**	0.343

1 = highest preference. P values are from ANOVA. The same letter in a column by individual sociodemographic variables indicates statistical identity (Fisher's test). For the overall mean the letters are read by row ($P < 0.001$).

there are few respondents that put green, the favourite colour, at the least aesthetic extreme.

That Australians have a relatively low level of preference for blue and yellow and a relatively high level of preference for brown and grey houses may indicate that they feel that houses should not stand out in the landscape but blend in with Australian natural tones. The relatively high level of preference by Asians for yellow and blue and their relatively low level of preference for brown may relate to cultural factors, with yellow being associated with good fortune. The high level of preference for blue among Europeans and the low level of preference for grey and brown may relate to the association of blue with Mediterranean holiday towns and the association of brown and grey with northern European weather. However, this is speculation that needs to be explored by qualitative research. A logical development from the present study would be to test combinations of alternative attributes, rather than one attribute at a time, as there may well be synergistic effects. It may also have been that the ways in which other variables were kept constant in the specific choices has affected those choices. For example, keeping the same number of houses in the density choice, rather than the same area, may have affected preferences. Also, the nature of our background may have influenced preferences, given that visual aesthetic impressions of suburban garden scenes can be influenced by proportions of colours (Ma *et al.* 2020).

The preferences we found may help planners to adjust the attributes of new suburban developments to cater for different subsets of people. For example, a subdivision designed for young Australian professionals and viewed by them from afar might be at the base of hills, fit in with the topography, be of medium- to low-density and would not be stylistically diverse or excessively brightly coloured. The major planning lesson from our work is that collaborative planning with local people will be necessary to maximise the aesthetic utility of new suburban developments. Because such developments are often as visible to those that pass them by as well those that live in them, consultation needs to be wide. It is unlikely that the aesthetic tastes of landscape planners will be fully shared by those whose lives intersect with their products.

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(accepted 10 October 2022)

ATTRITION OF BUSH TREES AFTER SUBURBAN DEVELOPMENT IN HOBART, AUSTRALIA

by Abiodun Tolulope Sobowale and Jamie B. Kirkpatrick

(with two text-figures, one table and one appendix)

Sobowale, A.T. & Kirkpatrick, J.B. 2022 (i:xii) Attrition of bush trees after suburban development in Hobart, Australia. *Papers and Proceedings of the Royal Society of Tasmania* 156: 89–93. ISSN 0080-4703. School of Geography, Planning, and Spatial Sciences, University of Tasmania, Private Bag 78, Hobart, Tasmania 7001, Australia. (SAT, JK*). *Author for correspondence. Email: j.kirkpatrick@utas.edu.au

The patterns and correlates of native tree loss after suburbs are built in forest and woodland are poorly known yet can be important for nature conservation and scenic amenity. We use Hobart, Tasmania, Australia, to determine the rate of such tree loss and the factors that relate to this. Twenty suburbs in Hobart that had transitioned from native vegetation to suburbs between 1946 and 2021 were randomly sampled. Ten cadastral parcels that were native forest or woodland in 1946 were randomly selected from each suburb. Data on tree and housing density for years 1946, 1971, 1996 and 2021 were obtained from stereoscopic aerial photographs. Correlation and multiple regression were used to analyse the relationships between tree loss rates and house numbers, mean block size, biophysical variables, and sociodemographic variables. The mean annual percentage loss of trees between 1946 and 2021 was 1.03%, while data on tree decline after houses were built indicated a mean annual percentage loss of 0.18%. Loss between 1946 and 2021 at the suburb scale was predicted by a multiple regression model that constituted number of houses in 1996, mean household income and mean number of people per household. This model reflected the surge of tree removal with house building, the tendency of people with high income to have trees in their gardens and the tendency for new suburbs to be occupied by young families to a greater degree than old suburbs. The rate of original tree loss after house construction is low, but points to a need to provide a steady stream of substitute trees.
Key Words: native tree, tree loss, environmental predictors, socioeconomic predictors, implications for planning.

INTRODUCTION

There has been a global decrease in trees in cities (Nowak & Greenfield 2020). The ongoing expansion of Australian suburbia and the concurrent densification of houses in older suburbia may have recently reversed a tendency for trees to increase in number between 1961 and 2006 in Australian suburbia (Kirkpatrick *et al.* 2011). In the decade between 2005 and 2015 there was net tree cover loss in all 14 suburbs of Hobart, Australia, monitored by Timilsina *et al.* (2020). A razed block approach to urban renewal has contributed towards tree loss in Perth, Australia (Brunner & Cozens 2013). Yet, five of six inner-ring suburbs of Melbourne, Australia, had tree cover increases between 2010 and 2015, despite densification (Kaspar *et al.* 2017).

The above studies pertain to all trees in the city, but some trees can be more important than others. For example, in some circumstances non-native trees can contribute more to biodiversity conservation and ecosystem services than native trees (e.g., Schlaepfer *et al.* 2020) and can support more native wildlife (Daniels & Kirkpatrick 2006). However, there are many circumstances in which the original native trees that survive suburbanisation contribute disproportionately to amenity and conservation values, as in Hobart, Tasmania, where two of the eucalypts that dominate the local forest are critical habitat for threatened bird species. Because they are in suburbia, they are buffered against loss of floral and other resources in drought years. There has been no work on the loss of *Eucalyptus viminalis*, the habitat tree for the Forty-spotted Pardalote *Pardalotus quadragintus*; however, between 1997 and 2005/8, 494 mature remnant trees of *Eucalyptus globulus*, the habitat tree for the Swift Parrot *Lathamus discolor*, were felled in the suburb of Mt Nelson (Allchin *et al.* 2013). Understanding the rate and correlates of tree attrition after suburbanisation might help to develop strategies for replacement of critical native tree species.

Our aims were to determine the rate of original tree loss in Hobart and its predictors, if any. Hobart was selected as a study area as a large proportion of suburban development since World War 2 has taken place in native woodland and forest.

METHODS

Sample selection

Twenty locations, each within a suburb, were selected randomly within the 2021 built-up area of Hobart (fig. 1). Selections were rejected, and followed by another selection, if they were not woodland or forest in the 1940s or were within the same suburb as a previous selection. Ten cadastral parcels were randomly selected at each of these locations. A cadastral parcel was rejected, and followed by another selection, if it did not have native trees in the 1940s, did have a house in the 1940s or did not have a house in 2021.

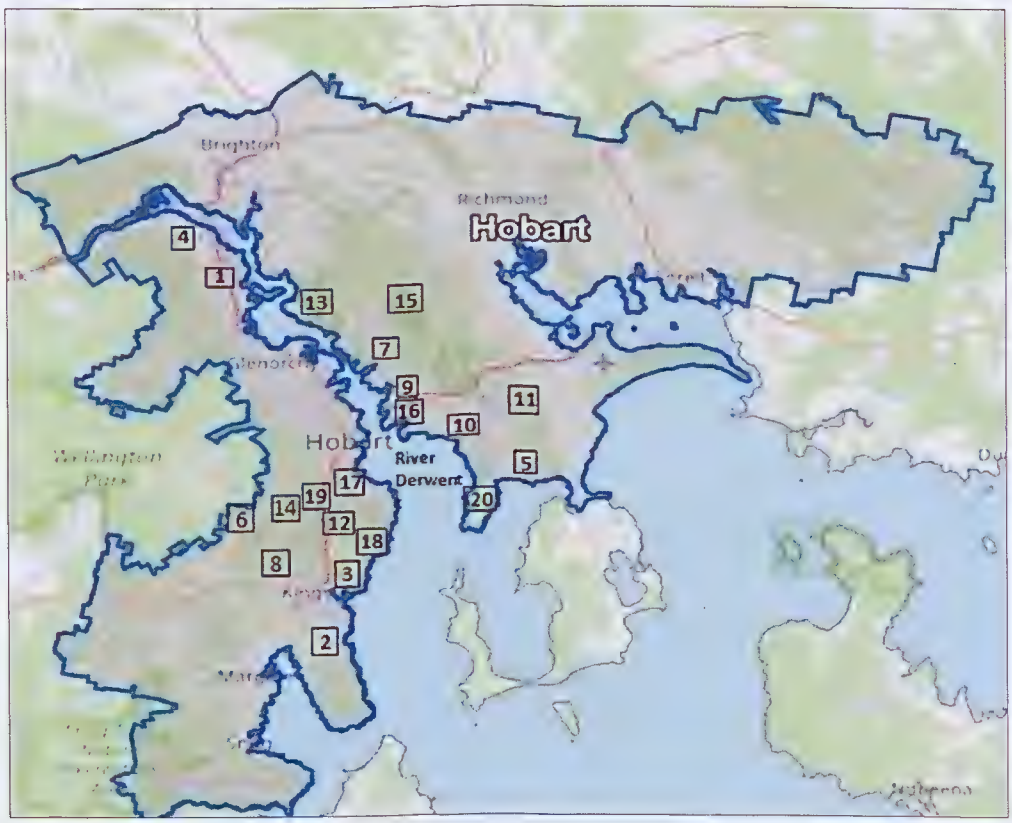

FIGURE 1 – The randomly selected suburbs in Greater Hobart, Tasmania, Australia. Key: (1) Austins Ferry, (2) Blackmans Bay, (3) Bonnet Hill, (4) Claremont, (5) Clarendon Vale, (6) Fern Tree, (7) Geilston Bay, (8) Kingston, (9) Lindisfarne, (10) Mornington, (11) Mount Rumney, (12) Mount Nelson, (13) Otago, (14) Ridgeway, (15) Risdon Vale, (16) Rosny Park, (17) Sandy Bay, (18) Taroona, (19) Tolmans Hill, (20) Tranmere.

Data collection

The number of native trees was counted for each of the ten cadastral parcels at each of the locations (fig. 1) in each year 1946, 1971, 1996 and 2021, using the best available stereoscopic aerial photographs. The number of houses on each cadastral parcel was also counted for each year.

The area of each cadastral parcel was determined using the area tool on the cadastre layer in LISTmap. Mean annual rainfall (mm) and mean annual temperature (°C) were extracted from climate layers in LISTmap. Elevation (m) was extracted from the topographic layer in LISTmap. Data by suburb were extracted from the 2016 Census for median annual household income ($AUD), the percentage of people with academic qualifications at Bachelor level or above, median age (years), females (%), the percentage of employed people in professional occupations and the mean number of persons per household (https://abs.gov.au/census/find-census-data/quickstats/2016/POA7304)

Data analysis

Means for all variables that pertained to the cadastral parcel level were calculated for each suburb. The percentage of trees that survived from 1946 was calculated for 1971, 1996 and 2021. One way ANOVA with Fishers test was used to test whether these percentages varied significantly between years ($P < 0.05$).

The 'Best Subsets' routine in Minitab16 (Minitab 16 Statistical Software 2010) was used to determine the most explanatory multiple regression models with 1, 2 and 3 predictors for the mean percentage of 1946 trees surviving in 2021. The predictors consisted of mean parcel size, number of houses in each of 1971, 1996 and 2021, the two climatic variables, elevation, and the socioeconomic and demographic variables.

RESULTS

In the 75 years between 1946 and 2021 there was an annual average loss of 1.03% of the trees present in 1946 per annum. By 1971, 68% of the 1946 trees survived, declining to 38% in 1996 and 20% in 2021. In the period 1996–2021, including only the ten suburbs with houses on all blocks in 1996, the annual loss was 0.18%, compared to an average annual loss of 0.72% when including all suburbs. The retention means for 1971, 1996 and 2021 were different from each other (ANOVA, $F = 60_{2,57}$, $P < 0.001$), despite considerable variability in each year (appendix 1). In Blackmans Bay, trees disappeared very rapidly, possibly due to clearing for subdivision. In other suburbs the loss

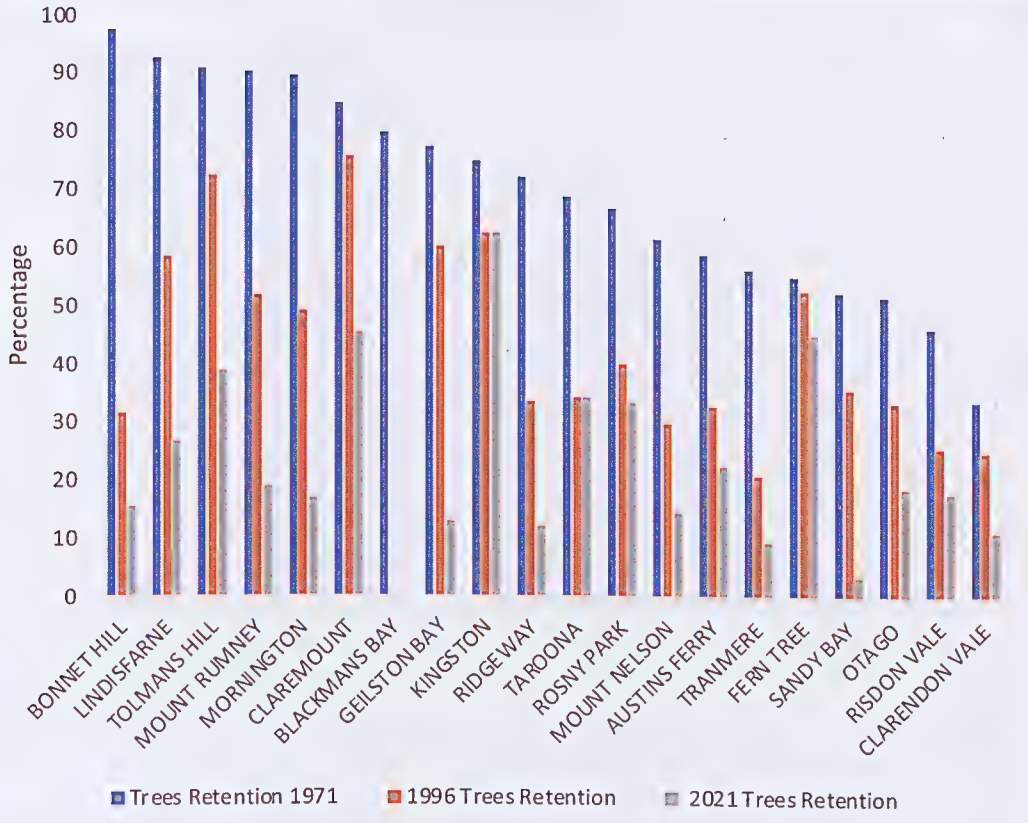

FIGURE 2 – The percentage retention of trees extant in 1946 in 1971, 1996 and 2021 by suburb.

TABLE 1

Best model to predict the percentage of 1946 trees surviving until 2021 (SE = standard error)

Predictors	Coefficient	SE Coefficient	T-statistic	Probability
Constant	65.44	26.67	2.45	0.026
Houses 1996	2.4358	0.7555	3.22	0.005
Income ($AUD)	0.0003078	0.0001179	2.61	0.019
Persons per household	–36.22	13.10	–2.77	0.014

was more gradual. At Taroona, tree loss was zero in the last 25-year period (fig. 2, appendix 1).

In the best model to explain retention (%) by 2021 (R^2 = 46.3 %, R^2 (adjusted) = 36.2%), the percentage survival of 1946 trees in 2021 was directly related to household income and the number of houses in 1996, but inversely related to the average number of people per household (table 1).

DISCUSSION

This study found much of the tree attrition on suburban blocks took place with the construction of houses and gardens. Once houses were built, the rate of attrition declined to one-fifth of the overall rate, indicating a likelihood that some of the original trees might survive for their full life spans of several hundred years. There may also be regeneration in gardens from the original trees, a phenomenon that has been observed in Hobart (Husband & Kirkpatrick 2021).

Most of the variables included in the analyses proved not to be predictive of loss. The three variables that were in the best model to explain tree retention in 2021 included house numbers in 1996. Suburbs with low house numbers in 1996 lost a larger proportion of trees between 1996 and 2021 because of house and garden establishment compared to suburbs where houses and gardens were already established. Where trees survive the establishment of new houses and gardens, they have a much lower probability of loss.

The second component in the model, household income, and its partial surrogate, house price, have long been established to positively predict trees in suburbia in Australia (Kirkpatrick *et al.* 2007, 2011; Kendal *et al.* 2012). There is more variability in the United States

with Heynen and Lindsey (2003) not finding income to be a predictor of trees in suburbia, in contrast to other investigators (Iverson & Cook 2000, McDonald *et al.* 2021). Timilsina *et al.* (2020) found that tree loss was greater as income declined in Hobart suburbs, consistent with our results for native trees.

The third component in the model suggests that large households tend to destroy native trees. This seems an unlikely hypothesis, even if households with children might be precautionary in removing perceived dangerous trees. Large households are often associated with low incomes (Schultz 2005), but in this case the association may not be with income, but with the recency of house establishment. New housing developments are often occupied by young families, whereas in older suburbs many houses are occupied by only one or two people. Thus, we interpret this variable as a surrogate for time since housing development. It may be the more recent the time of establishment the greater the tree loss from housing development.

Although the rate of original tree loss is not high once housing is established on blocks, it is desirable that those tree species that are habitat for threatened birds are maintained in the suburban landscape. To provide such habitat, it is desirable that regeneration in gardens is allowed, or local native trees planted. Planting of *Eucalyptus viminalis* or *E. globulus* requires large blocks, as both tree species can exceed 70 m in height in well-watered situations, but another species of habitat importance for threatened Swift Parrot, *Eucalyptus ovata*, is lower in maximum height.

Most planning schemes recognised by the Tasmanian Planning Commission contain significant tree registers that exclude native trees (Tasmanian Planning Commission 2022). There is a need for spatial application of targeted policies in planning schemes and the integration of approaches that protects native trees in land-use strategies to address the decline of the native trees population in the face of current housing need pressures.

ACKNOWLEDGEMENTS

We acknowledge the muwinina people – the traditional owners of the lutruwita/Tasmania Aboriginal land on which this research was conducted and thank them for protecting this island and its ecosystems since time immemorial. We are grateful to LISTmap and the other spatial resources provided by the Tasmanian State Government without which this work would not have been possible.

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(accepted 16 September 2022)

APPENDIX 1
Number of trees and houses by suburb

Suburb	Trees 1946	Houses 1946	Trees 1971	Houses 1971	Trees 1996	Houses 1996	Trees 2021	Houses 2021
Austins Ferry	83	0	51	8	24	13	16	13
Blackmans Bay	26	0	18	0	0	10	0	10
Bonnet Hill	797	0	773	0	250	9	126	10
Claremont	39	0	32	6	24	10	14	12
Clarendon Vale	116	0	39	9	29	11	13	12
Fern Tree	120	0	67	9	62	14	47	14
Geilston Bay	72	0	56	2	37	6	11	12
Kingston	38	0	25	3	16	9	12	12
Lindisfarne	52	0	44	10	28	10	11	11
Mornington	59	0	53	7	29	9	10	14
Mount Rumney	332	0	300	2	172	6	63	13
Mount Nelson	145	0	89	7	43	10	21	10
Otago	294	0	152	2	98	10	55	10
Ridgeway	247	0	178	5	83	8	30	10
Risdon Vale	39	0	18	10	10	10	7	10
Rosny Park	34	0	24	10	15	10	10	13
Sandy Bay	84	0	44	2	30	4	3	12
Taroona	32	0	22	2	11	10	11	10
Tolmans Hill	99	0	79	0	59	5	25	7
Tranmere	105	0	59	1	22	2	10	10

MYRMECOLOGY IN TASMANIA – A HISTORICAL SUMMARY, SYNOPSIS AND PRELIMINARY CHECKLIST OF THE ISLAND'S ANTS (HYMENOPTERA: FORMICIDAE)

by Christian Mackay and Peter B. McQuillan

(with two tables, twelve plates and one appendix)

Mackay, C. & McQuillan, P.B. 2022 (i:xii) Myrmecology in Tasmania – a historical summary, synopsis and preliminary checklist of the island's ants (Hymenoptera: Formicidae). *Papers and Proceedings of the Royal Society of Tasmania* 156: 95–112. ISSN 0080-4703. School of Geography, Planning, and Spatial Sciences, University of Tasmania, Private Bag 78, Hobart, Tasmania 7001, Australia. (CM, PBM*). *Author for correspondence. Email: p.b.mcquillan@utas.edu.au

This paper contains a species checklist of the ants of Tasmania and an overview of their discovery including contributions of visiting and resident biologists since the earliest records from 1777 during Cook's third expedition to the Pacific. Tasmania has about 10% of the described ant fauna of Australia including almost half the genera and nine of the 13 Australian subfamilies. Our search of literature records and databased collections revealed 116 species, including two exotic species, and 25 species that have Tasmanian type localities. Alpine habitats and temperate rainforests have poor diversity while coastal heaths and lowland grassy woodlands are much richer in ants; sampled sites in natural environments yield between three and 34 species. Although Tasmania spans only four degrees of latitude and longitude, there is evidence of a moderate north-south and east-west gradient in species distributions, the latter associated with a strong gradient in rainfall, insolation and soil type.
Key Words: ants, biogeography, checklist, history, Tasmania.

INTRODUCTION

The island of Tasmania is the most southerly extension of the Australian landmass, and at 68 102 km², occupies about 1% of the land area of the continent. On long time scales, Tasmania is an intermittent continental shelf island that is connected to the mainland when sea levels drop by 120 m during glacial maxima (Lambeck & Chappell 2001). Tasmania has been largely isolated from mainland Australia since the penultimate interglacial (approximately 135 000–43 000 years ago). Falling sea levels sustained a relatively brief eastern land connection 43 000–14 000 years ago which is estimated to be about the time when humans first arrived (Lambeck & Chappell 2001).

Although glacial events may have facilitated the migration of biota, temperatures were significantly colder and forested environments much diminished (Kirkpatrick & Fowler 1998), limiting faunal interchange between Tasmania and mainland Australia. Tasmania currently presents some of the most challenging environments for Australian insects including cold, wet and deeply shaded habitats associated with mountains, one million hectares of acidic moorlands with high water tables and densely canopied cool temperate rainforests (Reid *et al.* 1999). There are examples from many invertebrate groups of a high degree of specialisation through adaptation and speciation to these environments (McQuillan *et al.* 1999), although this does not appear to be the case for most ant groups.

The novelty of Tasmania's insect fauna has drawn the interest of biologists since the early nineteenth century (e.g., Erichson 1842) and its persistently mesic climate has offered refuge to many insect taxa likely exterminated from mainland Australia by drying climates in the distant past (McQuillan 1993, Austin *et al.* 2004).

Here we provide an overview of the ant fauna of Tasmania (Hymenoptera: Formicidae) and give a historical account of the people and events that have made significant contributions towards our understanding of it. We then summarise some of the apparent biogeographical trends in the ant fauna and present a consolidated checklist of the species reliably recorded from Tasmania. The most recent paper devoted largely to the Tasmanian fauna is more than a century old (Forel 1913). In view of the renewed global interest in ants, this stocktake is timely.

Discovery of Tasmanian Formicidae

While there is no written record of Tasmanian Aboriginal people's encounters with ants, recorded Aboriginal names suggest familiarity with at least three species of Tasmania's ant fauna (Milligan 1859), but the first people of the island interacted with ants beyond direct encounters. Extensive native grasslands and other open habitats across Tasmania at European colonisation attest to a long history of indigenous land use (Gammage 2008, Fletcher & Thomas 2010) which favours certain ant taxa at landscape and regional scales in response to managed fire practices.

From the colonial perspective, the first Tasmanian ants were not so much discovered as declaimed. Large aggressive ants tormented early European explorers and feature unfavourably in early dispatches from Van Diemen's Land. In the summer of 1777 at Adventure Bay (Bruny Island), Captain James Cook's [or his surgeon naturalist William Anderson's] observation of "a large black ant, the pain of

whose bite is almost intolerable during the short time it lasts" (Cook 1784, p. 111) is as indicative of *Myrmecia forficata* or Inchman as Johann Fabricius' (1787) formal description of the species a decade later. In 1792 in the hinterland of nearby Recherche Bay, Fr Louis Ventenat, the provocative chaplain-naturalist aboard *La Récherche* on the D'Entrecasteaux expedition, slipped heavily upon a huge fallen trunk whereupon ants "swarmed over me in their thousands" (Plomley & Piard-Bernier 1993), a likely encounter with a large nest of *Anonychomyrma* a genus often associated with woody debris.

During early settlement in the northwest of the island, the pioneer surveyor James Calder relates how a member of his reconnaissance party "...lay in too close proximity to a hill of black ants (or black dragoons as we call them here) ..." and was stung repeatedly. He went on to explain that "...the maddened traveller sprung to his feet, pale with terror and howling with pain.... undressed and [ran] twenty yards off in an instant" (Calder 1858, p. 1); which points compellingly to a skirmish with *Myrmecia pilosula*. Long ago re-christened the "Jack Jumper" for its aggressive behaviour when provoked, this widespread bull-ant is familiar to most Tasmanians for its painful and potentially lethal sting (Brown *et al.* 2001). Some 3% of the Tasmanian human population is claimed to be at risk of anaphylaxis following injection of its peculiar venom (Wanandy *et al.* 2018). The larger members of this genus are locally termed "inchmen" (Morris 1898). The endemic *Myrmecia esuriens* (Fabricius) (pl. 1), the second ant species described from Tasmania, is likely to have been collected by Jacques Labillardière or Claude Riche at Récherche Bay in 1791 or 1792. However, Fabricius' (1804) description misallocated it to Cayenne in French Guiana via the collection of the Danish naturalist Julius von Röhr – somewhat ironic given that French Guiana, too, became an imperial prison camp rivalling Van Diemen's Land in its notoriety.

A more complete view of the insect fauna emerged from the efforts of newly resident naturalists during the nineteenth century (McQuillan 2014). For a decade from 1831, the Silesian sheep expert Adolphus Schayer was superintendent at the Van Diemen's Land Company's frontier enterprise at Woolnorth in the northwestern corner of Tasmania. A talented naturalist, Schayer dispatched several collections of local arthropods to the leading German entomologist Wilhelm F. Erichson in Berlin (Shattuck & McArthur 1995). Erichson authored a seminal work on the biogeography of Van Diemen's Land (Tasmania from 1856) based upon its arthropods, including five ants among 242 new species described from this material (Erichson 1842). This work, which was translated from German to English and reissued by Sarah Fogg (1859), includes the description of the important genus *Amblyopone* Erichson (pl. 2), which is the type-genus of the primitive Dracula ants of the subfamily Amblyoponinae (Forel 1893a).

Among other residents, Morton Allport, a Hobart lawyer and arguably the foremost scientist of the colony, submitted natural history specimens to the British Museum for two decades from the 1850s (Anonymous 1878). Among them may have been the type specimen of *Myrmecia pilosula* described by Frederick Smith in 1858. In his catalogue of the ants in the British Museum, Smith (1858) emphasised the newly minted Tasmania as distinct from the rest of the continent via the subheading ("Species of Australia and Tasmania"). As a young man Allport spent 1853 and much of 1854 in England where he seems to have made useful contacts among various museum curators. By the 1860s he was a Fellow and corresponding member of the Linnean and Zoological societies and of the Royal Colonial Institute in London. His collecting efforts resulted in various new species of Tasmanian insects being described by the British Museum entomologist Francis Walker which were annotated as "presented by Morton Allport esq." from 1855 onwards.

However, the provenance of some Tasmanian ants described in the nineteenth century is less certain, especially those obtained by non-resident collectors and passed on to European specialists for study. In 1866 the Austrian zoologist Gustav Mayr described *Pheidole tasmaniensis* from specimens possibly sourced via the hymenopterist Jules Frédéric Sichel. It is possible that these originated from the collections of the Australian Museum which is known to have donated natural history specimens to the expeditioners of the imperial Austrian *Novara* expedition (1857–59) (McQuillan *et al.* 2001). Similarly, an endemic Tasmanian bee described by Sichel was allegedly collected by this expedition although the frigate never visited the island.

The first decade of the nineteenth century yielded two important publications describing common Tasmanian ants. The French biologist Ernest André (1896) named a suite of cool climate species sourced from the Victorian Alps, seven of which extend to Tasmania. An Italian connection involved two common dolichoderine ants described by Carlo Emery (1898) at the University of Bologna. The types of *Iridomyrmex bicknelli* and *I. mattiroloi* were probably collected in Tasmania by the naturalists Odouardo Beccari and Enrico D'Albertis in February 1878 and lodged by them in the Museo Civico di Storia Naturale 'Giacomo Doria' in Genoa, along with other material from their expedition (Dowe 2016).

During a stopover in 1891 by the British survey sloop HMS *Penguin*, naval engineer and amateur entomologist James J. Walker collected 798 species of insects around Hobart which he donated to the British Museum (Anonymous 1892). From Walker's collection of ants Swiss myrmecologist Auguste Forel (1893b) described *Myrmecia walkeri* which was subsequently synonymised with *M. esuriens*.

Less common species were gradually discovered over the course of the twentieth century. Arthur Mills Lea, the resident Government Entomologist from 1899–1911, was an indefatigable entomologist who collected widely across the island. He wrote two important papers (Lea 1910, 1912) on the beetles inhabiting the nests of Tasmanian and Australian ants and submitted the hosts to Forel for identification. In addition to identifying Lea's material, Forel described three new species: *Chelaner leae, Polyrhachis*

PLATE 1 — *Myrmecia esuriens* endemic Tasmanian Inchman. Photo: J. Wood

PLATE 2 — *Amblyopone australis* the archetypal Dracula Ant. Photo: T. Daly

leae and *Ponera leae*. Lea's material also yielded the first Tasmanian records for some previously known mainland ants. Another cryptic ponerine, *Myopias tasmaniensis*, was later discovered by Lea near Hobart and subsequently described by Wheeler (1923).

Collecting in the vicinity of his Launceston home in the late 1920s, Vernon V. Hickman, later the invertebrate zoologist at the University of Tasmania, discovered uncommon ants such as the endemics *Fulakora punctulata* and *Notoncus hickmani* described by John S. Clark at the National Museum of Victoria. Fieldwork in the environs of the Otway Ranges by Clark in the summer of 1932 revealed a fauna of mostly cryptic species (*sensu* Andersen 1995) associated with cool wet forests on the northern margin of Bass Strait (Clark 1934a, b), at least ten of which have subsequently been found to occur in similar habitats in western Tasmania (Coy *et al.* 1993).

In the decades after World War II, visiting CSIRO ecologists conducted field surveys at various times and locations across Tasmania. Tom Greaves, John Calaby, Tom G. Campbell, Edgar F. Riek, John (P.J.M.) Greenslade and Robert W. Taylor (Taylor 1987, 1991) all made significant collections of ant material, now largely incorporated in the Australian National Insect Collection (ANIC) in Canberra (Upton 1997).

Biodiversity surveys since the late 1970s have yielded ants from locations not previously sampled. The natural values of the remote Franklin, Olga and Gordon river valleys in western Tasmania were surveyed in the mid-1970s ahead of proposed hydro-electric developments. The most comprehensive was the Lower Gordon River Scientific Survey 1976–78, and ants from these studies are preserved in the ANIC and the Tasmanian Museum and Art Gallery, Hobart. Although not formally published, the collection confirms low ant diversity but a strong contrast in species profile between the rainforest fauna and the adjacent heathy moorlands. Arthropods were sampled at 24 rainforest sites around the island by the National Rainforest Conservation Programme (Coy *et al.* 1993), and the ants were briefly documented by John Greenslade. These collections yielded rarely collected rainforest taxa such as *Discothyrea*, and several species of *Prolasius* that appear to be undescribed. An inventory of ants documented in the Tasmanian Wilderness World Heritage Area accounted for 24 species (Mallick & Driessen 2005).

Following his retirement to Devonport in 1989, the Jesuit priest and amateur myrmecologist Bede Lowery SJ (Majer *et al.* 2004) collected mainly in the north of the island and published valuable insights into local ant communities and their relation to vegetation (e.g., Lowery 1994, Lowery & Taylor 1994). He lodged several synoptic collections of Tasmanian ants, mainly collected between 1990 and 1995, in various state institutions. Although Lowery did not publish a Tasmanian species list in his lifetime, Bashford (1998) produced a catalogue of ant taxa from these collections entitled 'Tasmanian ant species collected by Bede Lowery'. However, we note from personally inspecting two of Lowery's synoptic collections that some samples were not taken in Tasmania and furthermore the catalogue includes one non-ant, a *nomen nudum*, a New Zealand species and several synonyms. Lowery estimated the Tasmanian ant fauna to be 150 species (Lowery & Taylor 1994). His core collection went to the Australian National Insect Collection (ANIC, Canberra) but all represent the important legacy Lowery made to myrmecology in Tasmania. Meanwhile, Semmens *et al.* (1992) largely drew upon specimens curated in Tasmanian public collections and historic records to publish a catalogue listing 72 species of local ants. A more contemporary perspective on much of the island's fauna has emerged from recent revisions of large genera such as *Monomorium* by Heterick (2001), *Camponotus* by McArthur (2007) and *Iridomyrmex* by Heterick and Shattuck (2011). Their recent fieldwork and re-examination of older museum material has resulted in the addition of numerous species records to our checklist.

MATERIALS AND METHODS

This checklist was collated from diverse sources including field sampling by the authors, institutional databases and formal and informal literature. Myrmecological literature was searched for Tasmanian occurrence records, and we have tried to list the earliest record documented by an author. While thorough, we acknowledge that our search may not be exhaustive and further records, or earlier records, may emerge in time. Physical collections of Tasmanian ants are widely scattered across various Australian public institutions as well as private collections. The most comprehensive repository is the Australian National Insect Collection, Canberra (ANIC) since much of the collecting work that has occurred in Tasmania was funded by the CSIRO. The largest ant collection in Tasmania resides at the Queen Victoria Museum and Art Gallery in Launceston (QVMAG) but includes a large proportion of un-curated material. Other smaller collections are also held by (i) the Tasmanian Museum and Art Gallery, Hobart (TMAG) which now includes the former Tasmanian Forestry Insect Collection (TFIC) and (ii) the Tasmanian Agriculture Invertebrate Collection, Hobart (TAIC) which is managed by the entomology team in the Plant Biosecurity and Diagnostics Branch of the Biosecurity Tasmania Division. In assembling this checklist, we inspected all local Tasmanian collections. Access to ANIC material was originally via the Australian Ants Online website, which is rich in distribution records but now subsumed in AntWeb (https://www.antweb.org. Accessed 28 July 2022) and AntMaps (https://antmaps.org/about.html) (Janicki *et al.* 2016, Guénard *et al.* 2017).

The species list represents material that was collected via many different sampling methods such as canopy fogging, pitfall trapping, hand sampling and litter sampling. Not all methods have been applied in all habitats and, to our knowledge, no method that targets hypogaeic ants has been tried in Tasmania. New species records for Tasmania reported here are supported by voucher specimens as indicated in the Appendix. Where a specimen has not yet been identified to species but is the only Tasmanian example for that genus, it has been included in the checklist as a genus only.

RESULTS

We found evidence for 116 species representing 45 genera and nine subfamilies inhabiting Tasmania (appendix 1). This is slightly more than one quarter of the size of the described ant fauna of nearby Victoria, but likely less once the fauna of the adjacent mainland is better understood (A. Andersen pers. comm.). A compositional summary of the fauna by genera is given in table 1. Three subfamilies, Dolichoderinae, Formicinae and Myrmicinae, account for the bulk of generic and species richness. Myrmicinae had the highest generic richness accounting for 31.1% of all genera. Formicinae contributes only 20% of genera but has higher species richness, 31.0% compared with 25.0% for Myrmicinae. Myrmeciinae and Ponerinae have moderate species diversity, while the four remaining subfamilies Amblyoponinae, Dorylinae, Ectatomminae and Proceratiinae together accounted for only 9% of species richness. Representation at genus level ranges from 2% to 100% of the described Australian fauna, with a median of 17.6% (table 2). The most speciose genera in Tasmania are: *Myrmecia* with 11 described species, *Iridomyrmex* (9), *Camponotus* (8), *Prolasius* (7) and *Polyrhachis* (7) (table 2, examples of species on pls 3, 4, 5).

TABLE 1 — Summary of Tasmania's ant fauna by genus and species for each subfamily

Subfamily	No. of genera	%	No. of species	%
Amblyoponinae	2	4.4	4	3.5
Dorylinae	2	4.4	2	1.7
Dolichoderinae	9	20.0	23	19.8
Ectatomminae	1	2.2	2	1.7
Formicinae	10	20.0	36	31.0
Myrmeciinae	1	2.2	11	9.5
Myrmicinae	14	31.1	29	25.0
Ponerinae	6	13.3	7	60
Proceratiinae	1	2.2	2	1.7
Total	**46**	**100**	**116**	**100**

DISCUSSION

Biology

Only limited published information is available on the distribution, feeding and habitat preferences of Tasmanian ants. An early observation of *Pheidole* in agricultural pastures noted that workers gathered the freely scattered eggs of grass-feeding Corbie Moths (*Oncopera* spp., Hepialidae) and stored them in their nests (Lea 1908), perhaps mistaking them for seeds. Bashford (1993) documented the activity of eucalypt seed-harvesting ants at a woodland site in northeastern Tasmania, while Lowery and Taylor (1994) summarised the nearby ant fauna in sclerophyll forest communities around Old Chum Dam (41°06'S, 148°03'E). The two species of Dorylinae found on the island are likely nest raiders and predators of other ants (Borowiec 2016). Seven genera of ants were recorded as food for local Echidna *Tachyglossus aculeatus* (Spencer & Richards 2009), and ants were present in 96% of scats and made up 55 ± 39% of their scat contents by volume in the study of Sprent and Nicol (2016). Ants are also a favoured dietary item of the Mountain Dragon *Rankinia diemensis* (Gray) (Robertson & Coventry 2019), emphasising their importance as food for other animals. A surprisingly rich fauna of 19 species of acarine mites living in Tasmanian ants' nests was described by Banks (1916) and two species of the inquiline silverfish genus *Australiatelura* are known from warmer parts of the island (Smith 2016).

TABLE 2 — Number of described species per genus in Tasmania compared to Australia

Subfamily	Genus	Tasmania	Australia	Tasmanian species as %	Reference for species richness in Australia
AMBLYOPONINAE	*Amblyopone*	2	8	25.0	Yoshimura & Fisher (2012)
	Fulakora	2	6	33.3	Yoshimura & Fisher (2012)
DORYLINAE	*Lioponera*	1	44	2.3	Borowiec (2016)
	Zasphinctus	1	13	7.7	Borowiec (2016)
DOLICHODERINAE	*Anonychomyrma*	4	14	28.6	Andersen (2007)
	Arnoldius	1	5	20.0	Andersen (2007)
	Dolichoderus	2	22	9.1	Shattuck (1999)
	Iridomyrmex	9	78	11.5	Heterick & Shattuck (2011)
	Linepithema #	1	1	100.0	Shattuck (1999)
	Ochetellus	2	4	50.0	Andersen (2007)
	Tapinoma	1	5	20.0	Andersen (2007)
	Technomyrmex	2	13	7.6	Bolton (2007)
	Turneria	1	2	50.0	Shattuck (1999)
ECTATOMMINAE	*Rhytidoponera*	2	76	2.6	Andersen (2007)
FORMICINAE	*Camponotus*	8	139	5.8	AntWiki (2022)
	Colobopsis	2	8	25.0	AntWiki (2022)
	Melophorus	2	93	2.2	Heterick *et al.* (2017)
	Myrmecorhynchus	2	5	40.0	Shattuck (1999)
	Notoncus	3	6	50.0	Andersen (2007)
	Nylanderia	4	9	44.4	Andersen (2007)
	Plagiolepis	1	6	16.7	Shattuck (1999)
	Polyrhachis	7	115	6.1	Andersen (2007)
	Prolasius	6	18	33.3	Andersen (2007)
	Stigmacros	1	48	2.1	Andersen (2007)
MYRMECIINAE	*Myrmecia*	11	89	12.3	Andersen (2007)
MYRMICINAE	*Austromorium*	1	2	50.0	Andersen (2007)
	Chelaner	4	43	9.3	Sparks *et al.* (2019)
	Colobostruma	3	15	20.0	AntWiki (2022)
	Epopostruma	3	20	15.0	AntWiki (2022)
	Mayriella	1	4	25.0	Shattuck & Barnett (2007)
	Meranoplus	3	59	5.1	Andersen (2007)
	Metapone	1	4	25.0	Taylor & Alpert (2016)
	Monomorium	3	39	7.7	AntWiki (2022)
	Orectognathus	1	18	5.6	Andersen (2007)
	Pheidole	4	53	7.5	Andersen (2007)
	Podomyrma	1	49	2.0	Shattuck (1999)
	Solenopsis	2	7	2.9	Andersen (2007)
	Strumigenys	1	49	2.0	Andersen (2007)
	Tetramorium	1	24	4.2	Andersen (2007)
PONERINAE	*Cryptopone*	1	1	100.0	Shattuck (1999)
	Hypoponera	2	10	20.0	Andersen (2007)
	Iroponera	1	1	100.0	Schmidt & Shattuck (2014)
	Myopias	1	5	20.0	Shattuck (1999)
	Platythyrea	1	5	20.0	Shattuck (1999)
	Ponera	1	4	25.0	Shattuck (1999)
PROCERATIINAE	*Discothyrea*	2	4	50.0	Shattuck (1999)

PLATE 3 — *Camponotus consobrinus* ascend trees at night to seek honeydew. Photo: T. Daly

PLATE 4 — *Polyrhachis (Campomyrma) femoralis.* Photo: T. Daly

PLATE 5 — *Iridomyrmex alpinus* tending pseudococcids under bark. Photo: P.B. McQuillan

Although fire regime is known to influence ant communities in southern Australia (e.g., Andersen & Yen 1985, York 2000), few studies have been undertaken in Tasmania. Driessen & Kirkpatrick (2017) found that ant activity was highest one year after fire in montane moorlands in western Tasmania.

Introduced species

Two exotic species are established, both dolichoderines. The invasive Argentine Ant *Linepithema humile* was accidentally introduced to Tasmania in the early1950s (*The Examiner* 22 Aug 1951, p.3, Anonymous 1977) and was subject to sustained eradication attempts by the state government until about 1980. It is now present in most of the larger settlements but does not seem to have penetrated far from urban habitats (PBM pers. obs.), although it can degrade native ant communities in gardens (Heterick *et al.* 2000). The White-footed House Ant *Technomyrmex albipes* is a tramp species of SE Asian origin (Wetterer 2013) while its native relative, *T. jocosus*, is also a common urban species attracted indoors to food in kitchens in Tasmania (PBM pers. obs.). However, the actual identity of Tasmanian populations of *Technomyrmex* remains uncertain and multiple introductions may be involved.

Some singular early records of mainland ants from the vicinity of ports may represent introductions or translocations. In the nineteenth century especially, maritime trade with mainland Australia and elsewhere involved numerous small ports scattered around the island. For example, *Dolichoderus doriae* is known from a single location near Port Arthur, and a likely candidate as a non-native ant (Shattuck 1999); certainly, its continued presence needs confirmation. There are also a few specimens of *Odontomachus* from Port Arthur taken in the first half of the twentieth century (AntWeb ANIC:32-031841), but the genus has not been detected in Tasmania since 1949.

Absences and simplification

A comparison of Tasmania's ant fauna with that of mainland Australia reveals a degree of simplification and some noteworthy absences, largely reflecting the fact that ant diversity strongly declines in cool, wet habitats. The funnel ants *Aphaenogaster* and coconut ants *Papyrius* are absent. The Meat Ant *Iridomyrmex purpureus*, Australia's archetypal "dominant dolichoderine" (Greenslade 1976), is also absent (Heterick & Shattuck 2011) although bioclimatic modelling (MaxEnt) based on presence records suggests contemporary northeastern Tasmania and the islands of Bass Strait could support it (CM, unpubl. data). The very widespread generalist *Rhytidoponera metallica* is also missing but is replaced in similar habitats by the closely related *R. tasmaniensis* (pl. 6).

One of the most widespread camponotines on mainland Australia, *Polyrhachis phryne*, is known from a single woodland location in the northern Midlands. *P. phryne* is a species complex and the identity of Tasmanian examples

needs further clarification (A. Andersen pers. comm.). Heteroponerine ants (tribe Heteroponerini), now included in the subfamily Ectatomminae (Camacho *et al.* 2022), remain unknown from Tasmania to date (Taylor 2011). Among the myrmicines which are common in forests and woodlands on mainland Australia, *Monomorium sordidum* is also unreported (Heterick 2001), as is the genus *Adlerzia*. *Podomyrma* and *Meranoplus* are rare in the island's ant communities and represented by one or only a few species. *Crematogaster* ants commonly tend the larvae of lycaenid butterflies in southern Australia but have never been reported by lepidopterists in this role in Tasmania (Eastwood & Fraser 1999), and there are no records of the genus in the state. In addition, *Crematogaster* species are rather conspicuous arboreal ants and with the extent of surveying in recent years it is reasonable to assume that they would have been detected by now if they were present on the island.

Curiously, some cool climate Bassian elements, such as the formicine genus *Pseudonotoncus* and the *Stigmacros* subgenera *Campostigmacros* and *Stigmacros*, appear to be absent. In summary, the modest ant diversity reflects a recurrent pattern in Tasmania's insect fauna of attenuation of species richness in widespread genera relative to the adjacent mainland (Kitching & Dunn 1999, Austin *et al.* 2004). Some well-known inquilines are also absent, with ant crickets (Myrmecophilidae) not so far reported from Tasmania (Otte & Alexander 1983) nor *Iphierga* case moths (PBM pers. obs.).

Simplification is also apparent in montane environments. An altitudinal transect on Ben Lomond (400–1400 m) in northeast Tasmania yielded 12 ant species compared to 109 species on a transect in the Snowy Mountains (400–2000 m) on the adjacent mainland (Bishop *et al.* 2016) and 170 species further north in Lamington National Park, southeast Queensland (300–1100 m) where there was a marked reduction in diversity at the highest sites (Burwell & Nakamura 2011).

Fringe distributions

A thermophilic group, ants display a similar distribution pattern to other warm-adapted animals such as butterflies, grasshoppers and reptiles, all of which show a strong decline in species richness with increasing latitude in Australia. Although spanning less than four degrees of latitude, the island fauna shows some north to south differences with *Arnoldius*, *Monomorium arenarium*, *Podomyrma turneri* and *Myrmecia urens* only reported from the north of the state. Key elements of the extensive Australian ant semi-arid fauna, most notably representatives of the "hot climate specialists" (in the typology of Andersen 1995), barely reach Tasmania. *Melophorus* is represented by two rare species in woodlands in eastern Tasmania, although both are common in similar habitats on the mainland. Similarly, *Meranoplus* is uncommon and represented by only three of the 200+ continental species (Andersen 2006). Among the mainland "toehold" taxa with distributions that reach to the northern fringe of Tasmania, the rare myrmicine *Metapone mathinnae*, which lives in association with termites, extends only to Flinders Island in Bass Strait (Taylor & Alpert 2016).

PLATE 6 —*Rhytidoponera tasmaniensis* at extrafloral nectary on *Acacia dealbata*. Photo: P.B. McQuillan

Unusual dominants

In the absence of some well-known ecological dominants, such as *Iridomyrmex purpureus* and the adaptable and widespread *I. chasei*, it is possible that Tasmanian ant communities are structured somewhat differently from others in the Australian temperate zone, lacking most hot climate specialists for example. This would be a productive line of enquiry in the future. Nevertheless, some typically stressful habitats support local dominants such as *Iridomyrmex alpinus* (pl. 5) in poorly drained cold sites at high elevation. This aggressive ant can maintain populous nests in plant detritus mounded above the level of the winter water table or between slabs of rock. It exploits a wide range of food including nectar, exudates from subterranean scale insects, and honeydew from psyllids and pseudococcids on woodland eucalypts at the tree line. In the dry forests of eastern Tasmania and in contrast to mainland Australia, it is uncommon to see noticeably large populations of any *Iridomyrmex*, even where several species are locally sympatric.

Cold tolerant taxa: high elevation species

Tasmania is characterised by mountainous topography and prevailing westerly airflows, resulting in steep environ--mental gradients of rainfall and temperature. Elevation across the island spans sea level to 1600 m and annual rainfall ranges from 380 mm to 6000 mm. Although this template promotes high diversity and endemism in some insect groups, it does not appear to have had a major effect on ant diversity except in cold wet environments. There is a strong attenuation of ant diversity above 900 m and only three species of ants occur commonly above the tree line. In addition to *Iridomyrmex alpinus*, *Camponotus hartogi* is a diurnally active species above 1000 m which roves flowering

PLATE 7 — Alpine heathland, central Tasmania. Habitat for *Myrmecia, Iridomyrmex* and *Camponotus.* Photo: P.B. McQuillan

PLATE 8 — *Eucalyptus pulchella* woodland, southeastern Tasmania. Habitat for *Myrmecia, Amblyopone, Rhytidoponera, Anonychomyrma, Iridomyrmex, Camponotus* and *Notoncus.* Photo: P.B. McQuillan

PLATE 9 — *Themeda-Austrodanthonia-Poa* native grassland, eastern Tasmania. Habitat for *Rhytidoponera, Pheidole, Monomorium, Epopostruma* and *Notoncus*. Photo P.B. McQuillan

alpine shrubs in search of nectar. *Myrmecia haskinsorum* occurs in alpine woodland and shrubland (pl. 7) up to 1200 m and is the most cold-tolerant of this distinctive Australian genus. Its close relative *M. pilosula* is recorded from sea level to at least 1000 m in Tasmania (Taylor 2015). A member of the *M. urens* group, *M. loweryi*, might be expected to occur in alpine Tasmania (Ogata & Taylor 1991) but is so far unreported there.

Montane and grassy woodlands (pl. 8) support up to ten species of ants locally (PBM pers. obs.) which is between a third and a half of local diversity in the grassy woodlands of the lowlands. The Dracula Ant *Amblyopone australis* (pl. 2) extends to montane woodland up to 850 m, where it is locally common, and often nests in and under decaying wood in contact with the soil and also beneath rocks. Similarly, this widespread species is more abundant at higher elevations in the mountains of southeast Queensland (Burwell & Nakamura 2011).

Cold tolerant taxa: winter active species

At elevations below 300 m winter temperatures in the soil over much of Tasmania are relatively benign due to the maritime nature of the island climate at middle latitudes. Indeed, contemporary winter minimum temperatures over large areas of Tasmania are typically higher than continental areas of Australia at much lower latitudes with considerably larger ant faunas (Bureau of Meteorology 2009). This suggests that summer conditions may be more influential in determining the profile of local ant faunas. While most Tasmanian ants are dormant over the coldest three or four months of the year (May to August) a few taxa such as *Notoncus* and *Rhytidoponera* (pl. 6) remain opportunistically active, e.g., *N. ectatommoides* in grassy areas and *N. spinisquamis* in forests with abundant leaf litter (PBM pers. obs). *N. hickmani* ascends late winter-flowering shrubs to access nectar at night. *Anonychomyrma biconvexa* can be active on bright days in July, the coldest month, trailing slowly on sunlit tree trunks, and occasional individuals of small formicines, possibly *Plagiolepis*, are also seen on tree trunks in winter (PBM pers. obs).

Shade tolerant taxa

Shade-tolerant ants such as *Anonychomyrma* and *Prolasius* are abundant in many forested areas of southern Australia dominated by tall eucalypts (e.g., Ashton 1979, Andersen 1986). *Prolasius* is the dominant epigaeic genus in Tasmanian temperate rainforest (Mesibov 1998), although the diurnal glossy *P. nitidissimus* is common in drier open forest where it forages on both the ground and on vegetation. The distinctive *Chelaner sculpturatus* and *Discothyrea* spp. are widespread in rainforest also. *Rhytidoponera victoriae* occurs under eucalypt canopy and tolerates shadier sites than the related but slightly larger *R. tasmaniensis* which also occupies open grassland (pl. 9). The seed harvester

PLATE 10 — Buttongrass sedgeland, northeast Tasmania. Habitat for *Myrmecia, Monomorium* and *Iridomyrmex*. Photo P.B. McQuillan

PLATE 11 — Coastal saltmarsh, eastern Tasmania. Habitat for *Nylanderia, Pheidole* and *Iridomyrmex*. Photo: P.B. McQuillan

Pheidole tasmaniensis is reported to be active only in direct sunshine (Bashford 1993) but will come to experimental baits in shade when conditions are sufficiently warm (PBM pers. obs.). As a generalisation, most Tasmanian formicines appear to be nocturnal foragers, whereas the majority of dolichoderines are diurnal.

Soil challenges

Soil conditions are highly variable in Tasmania (Cotching *et al.* 2009) and edaphic factors are known to affect the make-up of local ant communities (Greenslade 1976, Greenslade & Thompson 1981). Only a modest fauna is associated with the shallow acidic moorland soils (organosols) overlying infertile pre-Carboniferous bedrock or regolith which cover a million hectares of western Tasmania (Bowman *et al.* 2006). These soils support low productivity, mainly graminoid, vegetation in a perennially damp environment. Several species of *Iridomyrmex*, one of *Pheidole* and members of the *Myrmecia pilosula* group are prevalent across this habitat (pl. 10). A small but characteristic suite of species (*Iridomyrmex* cf *alpinus*, two *Pheidole* spp., *Colobopsis gasseri*) nesting in and under driftwood) and a *Nylanderia* sp.) forage on saline mud in Tasmanian saltmarshes (pl. 11) (Aalders *et al.* 2019, PBM pers. obs.). The fertile but clay-rich soils derived from Jurassic dolerite which underlie much of central and eastern Tasmania (Osok & Doyle 2004) can be relatively rich in ants. A rocky mantle overlies these soils in many places and provides thermally favourable habitat. Stabilised sand sheets of late Pleistocene origin extend inland for tens of kilometres and provide extensive, free-draining soils in northeastern Tasmania. These are vegetated by heathlands and open woodland, and more than 30 species of ants may occupy a single site in this part of the island. Coastal sand specialists include *Monomorium arenarium* and *Camponotus terebrans* (McArthur *et al.* 1997) while *Iridomyrmex bicknelli* can maintain nests in coastal dunes as well as other soil types (Heterick & Shattuck 2011). However, the conspicuous funnel ant genus *Aphaenogaster*, common on similar soils in the adjacent parts of Victoria (Andersen 1986), appears to be absent.

Arboreal ants

The arboreal ant fauna is modest in Tasmania compared to eastern mainland Australia (Majer *et al.* 2001) consistent with the overall latitudinal trend to lower diversity. Local shrubs and trees offer seasonally abundant liquid food resources such as floral nectar and carbohydrate exuded from extrafloral nectaries on *Acacia* (pl. 6). Ants are also attracted to honeydew secreted by sap-feeding insects including: Homoptera: Psyllidae (on foliage), Pseudococcidae (under bark and on roots), Eriococcidae and Eurymelidae (mainly on petioles and midribs). A wide range of ants exploit these arboreal opportunities, including various species of *Anonychomyrma, Ochetellus, Camponotus, Colobopsis, Myrmecorhynchus* and *Prolasius*, along with *Myrmecia pilosula* and *M. urens* while *Myrmecorhynchus* species commonly nest in elevated wood (Shattuck 2015). Steinbauer (1996) documents the consumption of dried exudates (manna) at hemipteran feeding sites on eucalypts *Eucalyptus obliqua* by *M. pilosula, Camponotus* sp. and *Iridomyrmex* sp. *Iridomyrmex mattiroloi* ascends the rainforest shrub *Eucryphia lucida* in search of nectar (Ettershank & Ettershank 1990). In open woodland, loose columns of *Camponotus consobrinus* (pl. 8) are commonly seen ascending eucalypts at night during the warmer months (PBM pers. obs.). *Technomyrmex jocosus* often nests under bark near the base of large woodland trees.

Local diversity in a few genera

Tasmania is a hotspot for only a few taxa. The formicine *Prolasius* is common and diverse in cool environments where its modest-sized nests are associated with rotten logs or occur under rocks or moss (McAreavey 1947). Most *Prolasius* species are nocturnal but an exception is the glossy black *P. nitidissimus* which forages on *Acacia* and other tall shrubs in daylight. There is a moderate diversity of inconspicuous taxa on the island such as the subfamily Ponerinae and the myrmicine tribe Attini (*sensu* Ward *et al.* 2014) with eight species recorded (excluding *Pheidole*).

Local species richness of ants in Tasmania varies by an order of magnitude across sampled sites (most ranging from about one to ten hectares in extent). Spot estimates vary from three species in alpine herb-fields (PBM pers. obs., pl. 7) to 34 at some coastal locations (Lowery 1995). King Island (1098 km^2) at 39°S in Bass Strait is reported to have 34 species (Lowery 1995), comparable in size to the fauna on other temperate continental islands such as Britain and Santa Cruz Island offshore from California (Wetterer *et al.* 2000).

Few endemics

There are relatively few endemic ant species in the fauna, comprising just 5% or so of the total, while no genera are restricted to the island. The most conspicuous endemic is the Tasmanian Inchman *Myrmecia esuriens* widespread from near sea level to montane woodland where its colonies occur in well-decayed logs and under rocks at elevations up to 1000 m. In open woodland, the small *Iridomyrmex mattiroloi* is probably the most widespread of the endemic dolichoderines. In the western rainforests *Prolasius* may have several species confined to the island (pl. 12) (J. Greenslade pers. comm.) but the genus is poorly described, and a number of collections cannot be assigned to currently described species with confidence, not least because of the very poor condition of relevant type material.

Unexpected disjunctions in present-day distributions hint at past changes in connectivity between populations, although human-mediated transfer cannot be ruled out in some cases. The tropical dolichoderine genus *Turneria* has an outlying presence in eastern Tasmania about 800 km south of the nearest location to the north (Shattuck 2011). *Iridomyrmex meridianus* is currently known from populations in the extreme southwest of Western Australia and a likely related species in Tasmania, a separation of some 2000 km (Heterick & Shattuck 2011). *Nylanderia*

PLATE 12 — *Nothofagus* rainforest, western Tasmania. Habitat for *Prolasius*, *Monomorium* and *Discothyrea*. Photo: J. Veen

tasmaniensis has recently become established in New Zealand (Ward & Edney-Browne 2015), a new addition to the strongly adventive ant fauna there (Ward *et al.* 2006).

THE FUTURE

Despite ants being a relatively well-studied group in Australia, there is clearly further taxonomic work needed on the Tasmanian fauna. Most ant sampling in Tasmania has been opportunistic or the result of limited surveys of litter fauna or regional biodiversity. Large areas of the state remain poorly surveyed for ants and certain habitats including saltmarshes, native conifer forests and sedgelands are under-explored. Further species are likely to be revealed by modern taxonomic revision (Sparks *et al.* 2019, Andersen *et al.* 2020) of several common genera such as *Prolasius*, *Pheidole* and *Anonychomyrma* where species are not fully resolved. Further work should include *Nylanderia* which is under-described in Australia (Williams *et al.* 2022) and species with uncertain distributions such as *Myrmecia fulviculus*. The checklist presented here does not account for the total Formicidae of the island but is more a starting point for further engagement.

Tasmanian ants have considerable cultural value too. The Jack Jumper is familiar to many residents as a health hazard (Brown *et al.* 2003) and most children are schooled to recognise and avoid it. It features in routine risk assessment for outdoor excursions and is a driver of medical desensitisation practices. The Jack Jumper has also been adopted as the mascot for a major sporting franchise. There have been public education campaigns since the 1950s, beginning with Argentine Ants, and biosecurity anxieties around maintaining the relative pest-free status of Tasmania include pest ants present on the mainland. The opportunities for progressing ant studies are vast, with the timely emergence of online technical resources such as comprehensive keys and maps plus citizen science initiatives for reporting field discoveries such as iNaturalist. Ants have also been exploited as indicators of ecosystem condition, and habitat restoration projects can use ant community composition as a marker of progress (Andersen 1990, Bisevav & Majer 1999). To these important ends, synoptic and archival collections in Tasmania should be promoted to better support local initiatives.

ACKNOWLEDGEMENTS

We are grateful to Nicky Meeson of Bicheno for access to her collection of Tasmanian ants and Craig Reid who assisted us with access to the collection of the Queen Victoria Museum and Art Gallery, Launceston. Alan Andersen of Charles Darwin University was generous with his comments

which clarified our understanding of the fauna. The late John Greenslade kindly shared his insights into *Prolasius* with us. The efforts of two referees much improved our manuscript.

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(accepted 27 October 2022)

APPENDIX 1
Preliminary checklist of the ant fauna of Tasmania[1]

Subfamily	Taxon	Earliest found TAS record[2]
AMBLYOPONINAE	*Amblyopone australis* Erichson, 1842	Erichson (1842)
	Amblyopone longidens Forel, 1910	1991 QVMAG:12:5501
	Fulakora gracilis (Clark, 1934)	Brown (1960)
	Fulakora punctulata (Clark, 1934)	Clark (1934)
DORYLINAE	*Lioponera larvata* (Wheeler, 1918)	1991 QVMAG:12:5504
	Zasphinctus steinheili Forel, 1900	Lowery & Taylor (1994)
DOLICHODERINAE	*Anonychomyrma biconvexa* (Santschi, 1928)	Bashford (1993)
	Anonychomyrma itinerans (Lowne, 1865)[3,6]	Forel (1913)
	Anonychomyrma nitidiceps André, 1896	Bashford (1993)
	Anonychomyrma procidua (Erichson, 1842)	Erichson (1842)
	Arnoldius sp.	1992 ANIC:32-001357-678
	Dolichoderus australis André, 1896	1991 QVMAG:12:6006
	Dolichoderus doriae Emery, 1887	Forel (1913)
	Iridomyrmex alpinus Heterick & Shattuck, 2011	Heterick & Shattuck (2011)
	Iridomyrmex cf *alpinus*	A. Andersen pers. comm.; in lowlands
	Iridomyrmex bicknelli Emery, 1898	Emery (1898)
	Iridomyrmex calvus Emery, 1914	Heterick & Shattuck (2011)
	Iridomyrmex dromus Clark, 1938	Heterick & Shattuck (2011)
	Iridomyrmex mattiroloi Emery, 1898	Emery (1898)
	Iridomyrmex cf *meridianus* Heterick & Shattuck, 2011	Heterick & Shattuck (2011); A. Andersen pers. comm.
	Iridomyrmex niger Heterick & Shattuck, 2011	Heterick & Shattuck (2011)
	Iridomyrmex splendens Forel, 1907	Heterick & Shattuck (2011)
	Iridomyrmex suchieri Forel, 1907	Heterick & Shattuck (2011)
	Linepithema humile (Mayr, 1868)[4]	1951 ANIC:32-001598
	Ochetellus glaber (Mayr, 1862)	1991 QVMAG:12:5472
	Ochetellus punctatissimus (Emery, 1887)	Forel (1913)
	Tapinoma minutum Mayr, 1862	Lowery & Taylor (1994)
	Technomyrmex albipes (F. Smith, 1861)[4]	Shattuck (1999); may be *T. jocosus*
	Technomyrmex jocosus Forel, 1910	1962 ANIC 32-029382-548; Bolton (2007)
	Turneria rosschinga Shattuck, 2011	Shattuck (2011)
ECTATOMMINAE	*Rhytidoponera tasmaniensis* Emery, 1898	Emery (1898)
	Rhytidoponera metallica Emery, 1898[5,6]	Emery (1887)
	Rhytidoponera victoriae (André, 1896)	Lowery & Taylor (1994)

Appendix 1 cont.

Subfamily	Taxon	Earliest found TAS record[2]
FORMICINAE	*Camponotus consobrinus* Erichson, 1842	Erichson (1842)
	Camponotus elegans Forel, 1902	McArthur (2007)
	Camponotus hartogi Forel, 1902	Lowery & Taylor (1994)
	Camponotus innexus Forel, 1902	McArthur (2010)
	Camponotus nigroaeneus (F. Smith, 1858)	McArthur (2007)
	Camponotus oetkeri voltai Forel, 1913	Forel (1913)
	Camponotus tasmani Forel, 1902	McArthur (2007)
	Camponotus terebrans (Lowne, 1865)	McArthur *et al.* (1997)
	Colobopsis gasseri Forel, 1894	Forel (1913)
	Colobopsis macrocephala Emery, 1894	Taylor & Brown (1985)
	Melophorus biroi Forel, 1907	Heterick *et al.* (2017)
	Melophorus castanopus Heterick, Castalanelli & Shattuck, 2017	Heterick *et al.* (2017)
	Myrmecorhynchus carteri Clark, 1934	1949 ANIC:32-010758-419
	Myrmecorhynchus emeryi André, 1896	Lowery & Taylor (1994)
	Notoncus ectatommoides (Forel, 1892)	Lowery & Taylor (1994)
	Notoncus hickmani Clark, 1930	Clark (1930)
	Notoncus spinisquamus (André, 1896)	Brown (1955)
	Nylanderia braueri (Mayr, 1868)	1991 TMAG: F032790
	Nylanderia obscura (Mayr, 1862)	1962 ANIC:32-036911-656
	Nylanderia rosae (Forel, 1902)	GABI_00671960(Museum) CSIRO Collection
	Nylanderia tasmaniensis (Forel, 1913)	Forel (1913)
	Plagiolepis exigua Forel, 1894	1991 QVMAG:12:5497
	Polyrhachis femorata F. Smith, 1858	1992 QVMAG:12:10924
	Polyrhachis fuscipes Mayr, 1862	Mayr (1866)
	Polyrhachis hexacantha (Erichson, 1842)	Erichson (1842)
	Polyrhachis leae Forel, 1913	Forel (1913)
	Polyrhachis patiens Santschi, 1920	Lowery & Taylor (1994)
	Polyrhachis cf *phryne* Forel, 1907	A. Anderson pers. comm.
	Polyrhachis semipolita André, 1896	Forel (1913)
	Prolasius convexus McAreavey, 1947	McAreavey (1947)
	Prolasius flavicornis Clark, 1934	Taylor & Brown (1985)
	Prolasius hemiflavus Clark, 1934	Taylor & Brown (1985)
	Prolasius nitidissimus (André, 1896)	Lowery & Taylor (1994)
	Prolasius pallidus Clark, 1934	Taylor & Brown (1985)
	Prolasius robustus McAreavey, 1947	Taylor & Brown (1985)
	Prolasius sp.	J. Greenslade pers. comm.
	Stigmacros barretti Santschi, 1928	Lowery & Taylor (1994)
MYRMECIINAE	*Myrmecia esuriens* Fabricius, 1804	Smith (1858)
	Myrmecia forficata Fabricius, 1787	Fabricius (1787)
	Myrmecia fulviculis Forel, 1913	Forel (1913) CASENT0907098
	Myrmecia fulvipes Roger, 1861	Forel (1913)
	Myrmecia haskinsorum Taylor, 2015	Taylor (2015)
	Myrmecia nigriceps Mayr, 1862	Forel (1913)
	Myrmecia piliventris F. Smith, 1858	Taylor & Brown (1985)
	Myrmecia pilosula F. Smith, 1858	Smith (1858)
	Myrmecia pyriformis F. Smith, 1858	Taylor & Brown (1985)
	Myrmecia simillima F. Smith, 1858	Forel (1910)
	Myrmecia urens Lowne, 1865	Clark (1951)

Appendix 1 cont.

Subfamily	Taxon	Earliest found TAS record[2]
MYRMICINAE	*Austromorium flavigaster* (Clark, 1938)	Lowery & Taylor (1994)
	Chelaner crinitus (Heterick, 2001)	Heterick (2001)
	Chelaner kilianii (Forel, 1902)	Heterick (2001)
	Chelaner leae Forel, 1913	Forel (1913)
	Chelaner sculpturatus (Clark, 1934)	Lowery & Taylor (1994)
	Colobostruma alinodis (Forel, 1913)	Forel (1913)
	Colobostruma elliotti (Clark, 1928)	1986 ANIC 32-003831-052
	Colobostruma froggatti (Forel, 1913)	Forel (1913)
	Epopostruma alata Shattuck, 2000	Shattuck (2000)
	Epopostruma natalae Shattuck, 2000	Shattuck (2000)
	Epopostruma quadrispinosa (Forel, 1895)	1991 QVMAG:12:5487
	Mayriella ebbei Shattuck & Barnett, 2007	Shattuck & Barnett (2007)
	Meranoplus curvispina Forel, 1910	Andersen (2006)
	Meranoplus fenestratus F. Smith, 1867	AntMaps.org (2022)
	Meranoplus puryi Forel, 1902	Andersen (2006)
	Metapone mathinnae Taylor & Alpert, 2016	Taylor & Alpert (2016)
	Monomorium arenarium Heterick, 2001	Heterick (2001)
	Monomorium fieldi Forel, 1910	Heterick (2001)
	Monomorium sydneyense Forel, 1902	Heterick (2001)
	Orectognathus clarki Brown, 1953	Taylor & Brown (1985)
	Pheidole concentrica recurva Forel, 1910	Forel (1910)
	Pheidole liteae Forel, 1910	Forel (1910)
	Pheidole tasmaniensis Mayr, 1866	Mayr (1866)
	Pheidole vigilans (F. Smith, 1858)	Taylor & Brown (1985)
	Podomyrma turneri (Forel, 1901)	1986 QVMAG:12:11967
	Solenopsis froggatti Forel, 1913	Forel (1913)
	Solenopsis insculpta Clark, 1938	2014 GABI_00998431(Database) Robson Simon Ant Collection
	Strumigenys perplexa (F. Smith, 1876)	Forel (1913) (as *leae* Forel)
	Tetramorium sp.	1992 ANIC 32-002510-854
PONERINAE	*Cryptopone* sp.	1991 ANIC 32-002563-253
	Hypoponera decora (Clark, 1934)	Bashford (1993)
	Hypoponera rectidens (Clark, 1934)	Taylor & Brown (1985)
	Iroponera odax Schmidt & Shattuck, 2014	Schmidt & Shattuck (2014)
	Myopias tasmaniensis Wheeler, 1923	Wheeler (1923)
	Platythyrea turneri Forel, 1895	Forel (1913)
	Ponera leae Forel, 1913	Forel (1913)
PROCERATIINAE	*Discothyrea bidens* Clark, 1928	1991 QVMAG:12:5425
	Discothyrea turtoni Clark, 1934	1974 ANIC 32-006760

1 Species are referenced by either a literature citation or catalogued specimens in an institutional collection.

2 Reference specimens are reported in the following format: year of collection, institution, accession number, e.g., 1991 ANIC 32-002524-321.

4 Introduced species.

3 *Anonychomyrma itinerans* is unlikely to occur in Tasmania; it is a species complex of the semi-arid zone and is absent from mesic southern Victoria (A. Andersen pers. comm.).

5 *Rhytidoponera metallica* is listed under Ant Maps as being present in Tasmania based on an 1887 manuscript by Carlo Emery. Given that *R. metallica* is easy to recognise and has not been reliably recorded since, we regard the location record as unreliable.

6 Species indented indicate their doubtful status in Tasmania.

MAWSON AND AMUNDSEN IN HOBART: ISSUES IN THE MAKING OF AN ANTARCTIC GATEWAY

by John Williamson

(with three plates)

Williamson, J. 2022 (i:xii): Mawson and Amundsen in Hobart: issues in the making of an Antarctic gateway. *Papers and Proceedings of the Royal Society of Tasmania* 156: 113–120. ISSN: 0080-4703. Head of Humanities, Fahan School, Sandy Bay, Tasmania 7005, Australia. Email: williamsonj1954@gmail.com

This paper examines some aspects of the growth of Hobart as an Antarctic gateway. Indigenous Tasmanians used the sheltered waterways of the Derwent Estuary as a base for maritime journeys into Storm Bay and beyond. After European colonisation of Tasmania (1803), the creation of Hobart as a major port for Antarctic and Southern Ocean exploration was then slowly built across more than a century of development. From the early nineteenth century, to the years before World War I, sealing and whaling vessels entered the Southern Ocean and some began to focus on the exploration of Antarctica. However, despite these many visits – including Douglas Mawson's Australasian Antarctic Expedition (1911–1914) and Roald Amundsen's Norwegian Antarctic Expedition (1910–1912) – the port of Hobart was not fully established as a significant hub for Antarctic exploration and science until well after the "Heroic Era" and the Australian Government had decided to establish scientific bases on the southern continent. This paper contributes to the discussion of the historical growth of Antarctic-focused port cities.
Key Words: Douglas Mawson, Roald Amundsen, Hobart, Antarctica, gateway, research hub.

INTRODUCTION

Much has been written about the importance of an Antarctic gateway (or, more recently, custodial ports) (Salazar *et al.* 2021), but little has been done to examine the historical development of these places or the processes that enable them to act as hubs for the Southern Ocean and Antarctica. This paper examines aspects of the development of Hobart as an Antarctic gateway port. This fairly recent term (Bertram *et al.* 2007, Roldan 2011), implies a coastal or island port, able by its proximity to the Antarctic to benefit from, and control access to, Antarctic and Southern Ocean resources, including fishing, tourism and scientific support (University of Canterbury 2020). Discussion of the phases of this slow development in Hobart include: the early use of the estuary of the River Derwent by the indigenous Muwinina people; use of the port of Hobart as it became established in the years after European colonisation; the increasing maritime traffic of the early and middle nineteenth century; the later nineteenth and early twentieth century, and "Heroic Era" expeditions of the Australasian and Norwegian Antarctic Expeditions. This discussion concludes with a brief analysis of the barriers and circumstances responsible for such slow and fragmented development of Hobart's status as a Southern Ocean and Antarctic hub. In fact, it was not until science became the main focus of national expeditions – after World War II – that Hobart began to be a more significant Antarctic port. In 2022 Hobart is indeed recognised as a global research hub for Antarctica.

Early use of the Derwent Estuary and port of Hobart

The estuary of the River Derwent is deep and well-protected from storm winds. The Muwinina people regularly used the waterways of southeast Tasmania including the River Derwent and the D'Entrecasteaux Channel as well as other coastal areas to explore and travel further south (Ling Roth 1890, Pearson 1938, Florek 2013). There is, for example, evidence of local indigenous people travelling as far as Eddystone Point, Maatsuyker Island and Pedra Branca (Aboriginal Heritage Tasmania 2018).

After European colonisation in 1803, the growing port of Hobart began increasingly to be used as a base for maritime activities in the Southern Ocean. During the first years of settlement convict ships deposited their wretched human cargo in Hobart, then went in search of seals or whales, returning to London with seal skins and whale oil to defray their costs. Sullivans Cove – the location of Hobart's port – was found to be a deep-water harbour; it was well protected from the savage winds that blew from the north and southwest; ships could be provided with fresh water and victuals, sailing crew, coopers and carpenters, engineering expertise, medical facilities; it was relatively close to sealing and whaling grounds and was well located at less than 2500 km from Antarctica (Kriwoken & Williamson 1993, Nash 2003). Hence, whalers and sealers from the 1790s had sought respite in the cove and other parts of the Derwent Estuary prior to, or after, their voyages south. John Biscoe arrived in Hobart in 1831 after his circumnavigation of the Antarctic continent and discovery of Enderby Land (Savours 1966). The expeditions of Dumont d'Urville (1837–1840) and

then Ross and Crozier (1839–1843), came to Hobart for its splendid port as well as its proximity to the Antarctic (Wood 2020). Bull in 1894 (Bull 1896), then Borchgrevink in 1898 (Swan 1979) both used the harbour facilities of Hobart. Captain Scott's ships *Morning* and *Terra Nova* also came to Hobart and were both here by early November 1903, on their way to relieve the *Discovery* Expedition on Ross Island (*The Mercury* 2 Nov. 1903, p. 4, 5 Nov. p. 4).

Despite all this activity through the port of Hobart, most of the polar scientific and exploratory work during the period 1840–1900 was in the Arctic and carried out from European ports. During the last half of the nineteenth century, Hobart had, it is true, developed considerable infrastructure for provisioning, repairing and docking many ships from fishing, whaling and other commercial fleets but as most of the focus of the European powers was towards the Arctic or Africa, the role of the port in Hobart had become one of convenience for those few expeditions going to the Antarctic. Once nations began to show serious intent in exploring Antarctica, Hobart became more attuned to the sight and sound of Antarctic and Southern Ocean expeditions and, according to one Tasmanian writer, Tasmania was becoming an important point of departure for Antarctic voyages (Kriwoken & Williamson 1993, p. 96). During the "Heroic Era" of Antarctic exploration some vessels did use Hobart's port facilities: indeed, two significant Antarctic expeditions, the Australasian Antarctic Expedition (1911–1914) and the Norwegian Antarctic Expedition (1910–1912) used the port of Hobart during their journeys. It is tempting to believe that these large and successful expeditions might have been the key to establishing, or at least enhancing, Hobart's reputation as an Antarctic gateway but it does not seem to have been the case.

THE AUSTRALASIAN ANTARCTIC EXPEDITION

The Australasian Antarctic Expedition (AAE 1911–1914) – of which Dr (later Sir) Douglas Mawson was the leader and chief scientist – was the first Australian-based and supported voyage of exploration and science to Antarctica. At a time of European exploration and imperialist efforts this expedition appeared to put Australia onto the international map as a new but significant nation. Mawson's qualifications in geology and his evident skills on expeditions to isolated places were part of the reason that he had been accepted onto Ernest Shackleton's *Nimrod* Expedition (1907–1909). During that expedition, Mawson was part of the first group to ascend Mt Erebus and also the virtual leader of the party that reached the South Magnetic Pole in January 1909 (Ayres 1999). After rejecting Scott's offer to go south on the *Terra Nova* voyage, Mawson decided instead to lead his own expedition. Once back in Australia, Mawson had sought to garner support from the prestigious Australasian Association for the Advancement of Science (AAAS) which gave their stamp of approval to Mawson's plans and pledged a significant sum of money towards the cost of the expedition (Australian Antarctic Division 2011). Finances were also raised by public subscription with substantial contributions coming from the Commonwealth and State governments, the British Government, and the Royal Geographical Society. Professor Sir David Orme Masson of Melbourne, and Professor Sir Edgeworth David of Sydney, were the primary members of the AAAS appointed to further the cause of the expedition and represent it in Australia (Douglas Mawson http://www.south-pole.com/p0000099.htm).

The plans for the AAE were ambitious and far ranging in terms of scientific data to be gathered but did not involve any attempt to reach the South Geographic Pole. Oceanic science was planned and in particular a survey of the coast of Macquarie Island some 850 miles southeast of Hobart. The ship would then head for the Antarctic mainland where a hut would be built and equipped for a party to spend a year; another party would then be deployed along the coast to the west and would be picked up the following year (Martin 1996, pp. 146–147). The arrival in Hobart of members of the expedition was staggered over several weeks, with the first senior expedition member to arrive being Frank Wild who spoke to *The Mercury* of the aims of the expedition and of their activities in Hobart (*The Mercury* 28 Oct. 1911, p. 8). Captain J.K. Davis of the *Aurora*, with all the crew and dogs, had sailed from London on 28 July 1911 (Jacka & Jacka 1991). They stopped at Cardiff to put on coal and arrived in Hobart on 4 November. *Aurora* sailed up the River Derwent and docked at Queens Wharf. Captain Davis commented that "Hobart was marked out by nature as the best base for ... the exploration of this portion of the Antarctic continent" (*The Mercury* 6 Nov. 1911, p. 2).

Over the next few weeks, under the direction of Frank Wild, over five thousand boxes, crates and packages were opened, checked, repacked and sorted. They were colour-coded according to which land party required them (Riffenburgh 2008, p. 48). On Monday 6 November, Mawson spoke with *The Mercury* and mentioned, in passing, that Tasmania had not given any money for the expedition nor even offered free docking and coal supply: he compared this with the generosity that the New South Wales government had offered to Shackleton in Sydney (*The Mercury* 7 Nov. 1911, p. 1). By the end of the month, however, the Hobart Marine Board had exempted the expedition's two ships, *Aurora* and *Toroa*, from all port fees (*The Mercury* 29 Nov. 1911, p. 6). The captain and crew were excellent ambassadors for their expedition: happily attending social gatherings and church services; talking at length about the expedition and helping with raising funds for their journey. Lord Denman, the Australian Governor General, reiterating the importance of this expedition, wished the expeditioners good luck in "bringing honour to the Commonwealth" (Fitzsimons 2011, p. 355). Mawson was guest at several dinners and lectures (Quilty 2021, p. 246), and *The Mercury* reported Mawson's reasons for exploring the area to the west of Oates Land: "It is the nearest part to Australia, and it should be Australia's special duty and her obligation to contribute to the world at large whatever ... store of secrets this land holds." (*The Mercury*

PLATE 1 — Mawson's Australian Antarctic Expedition on the *Aurora*, farewelled by a large crowd, leaving Hobart on 2 December 1911. (Photo: National Library of Australia Open Access nla.obj-142165822)

28 Nov. 1911, p. 6). Mawson and his expeditioners were, by the same token, well supported by the local community and these activities served to strengthen the bonds the people of Hobart felt for the southern continent as well as raising interest in the science of Antarctica. The *Aurora* left Hobart on Saturday 2 December 1911 and a vast throng crowded the wharf to say farewell (pl. 1), (Riffenburgh 2008, p. 55).

During the AAE, Mawson's own extraordinary, and ill-fated, sled journey offered the new nation its first national heroic legend two years before that of the Gallipoli campaign during World War I. The expedition's activity in Hobart strengthened the ties the people of Hobart felt for Antarctica as well as raising interest in the science of Antarctica. All of this was to bear fruit later in the twentieth century in the short term; however, there was a disjunction: neither Hobart's role in the AAE expedition (and in the BANZARE 1929–1931), nor the Australian Government's positive view of Antarctic exploration and the importance of this expedition, made Hobart any more important as a gateway to Antarctica than it had been before. It is true that Hobart provided a vital base and staging post for the AAE because of its location, services and personnel and it was immediately followed by, on some accounts, an even more successful expedition – the Norwegian Antarctic Expedition led by Roald Amundsen. And yet there was no immediate boost in visits by Antarctic expeditions, to the Ross Sea or the Antarctic sector south of Australia, from Hobart during the next 45 years even despite Mawson's proclamations of British Sovereignty in 1931 that would form the basis of Australia's Antarctic Territory in 1933. Hobart's capacity as a Southern Ocean or Antarctic port had not yet been realised.

NORWEGIAN ANTARCTIC EXPEDITION 1910–1912

In 1910 Roald Amundsen and the Norwegian crew left Oslo on the ship *Fram*. Their stated aim was to sail towards the North Pole. However, no sooner had they left than news reached them that the American expedition led by Robert Peary, had successfully reached the pole (April 1909). So, as a response, Amundsen decided to sail instead to the southern hemisphere to attempt to reach the South Geographic Pole before anyone else. This would be a significant boost in national pride for Norway which had, only recently (1905), achieved national independence from Sweden. This expedition involved reaching the South Pole, getting back successfully to their ship *Fram* in the Bay of Whales, Ross Sea, then sailing quickly to a port with good telegraphic services to spread the news of their success. As it seemed likely that the British expedition with similar ambitions led by Captain Scott was to sail from the Antarctic to Christchurch, Amundsen made the decision to send his own messages to the world from another port that was closer to the Ross Sea – Hobart. His expedition reached the Pole on December 1911 and, after this significant achievement, Amundsen

and his crew sailed to Hobart. When *Fram* sailed into the port of Hobart in March 1912 it was an exciting event, and more so when Hobart's citizens realised just what Amundsen had achieved and that he had come to Hobart to tell the world. What needs to be examined is how the Norwegian Expedition's presence in Hobart affected the city's status as a gateway to the south.

Fram had appeared unannounced in the Derwent Estuary on Thursday 7 March 1912. The ship was met by the pilot and continued up the river. "The surroundings [of Hobart Town] are beautiful and the soil evidently extremely fertile ... To our eyes it was ... a delight to look upon meadows and woods" (Amundsen 1912, p. 203). Signals to the Mount Nelson Signal Station stated that she was "*Fram* from the Bay of Whales, Antarctica" (*The Mercury* 8 March 1912, p. 4).

The Norwegian consul, James McFarlane, had previously written to the Premier, on 4 January 1912, requesting "dispensation from pilotage and tonnage dues ..."; the Premier's Department wrote to the Marine Board asking they comply with the request that the Marine Board grant the Norwegian Expedition the same facilities as they had granted to *Aurora* – i.e., remission of all port charges and fees. The Norwegian Consul thanked the Premier – "Hobart will be the first Port and probably the only Port in Australia that this ... expedition ... will visit" (Norwegian Consul to Premier Elliot Lewis, 4 January 1912, Tasmanian Archives and Heritage Office PSC2/1/2). *Fram* then dropped anchor some distance off Battery Point (pl. 2) and, after a time, Amundsen came ashore with the Harbour Master on the launch, *Egeria* (Amundsen 1912; *The Mercury* 7 March 1912, p. 4, Bomann-Larsen 2011). A Norwegian crew member, Hassel, noted that, "A. was carrying his telegram briefcase. I bet he won't let go of it" (Bomann-Larsen 2011, pp. 110–111).

The fact that *Fram* did not dock immediately is likely to have been, in part, because Amundsen's dogs had not been through the usual quarantine checks. Another reason could have been that the Norwegians had been instructed to say nothing about their success until the expedition's financial sponsors had received, and printed, the complete story (Australian National Maritime Museum 2017). Then there are conflicting accounts of the exact order of events. Amundsen's own diary claims that he went first to Hadley's Orient Hotel and a small room – not, however, to the wonderful *Amundsen Suite* that graces the hotel today: "Arrived at Hobart at 11 a.m. Went ashore with the doctor and harbourmaster, booked in at the Orient Hotel. Was treated as a tramp – my peaked cap and blue sweater – given miserable little room." (Huntford 1999, p. 514). His next move was to the Hobart General Post Office where he sent his Norwegian telegrams to King Haakon VII of Norway, Fridtjof Nansen (his mentor and owner of *Fram*) and to his own brother Leon. Professor Orheim said that the three telegrams were sent after 2pm on that day (https://amundsen.mia.no/en/resource/1910-1912-fram-expedition-2/, Bomann-Larsen 2011, Olav Orheim, pers. comm. 2012).

PLATE 2 — The *Fram* anchored in the River Derwent, 31 December 1912. (Photo: J.W. Beattie, https://www.timbowden.com.au/2012/02/01/blog-1/)

Amundsen had experienced trouble on previous voyages when news of his expedition's success had escaped before he could first tell his sponsors and his King. Consequently, prior to sending his telegrams from Hobart, Amundsen and his crew (pl. 3) were silent about what they had achieved. In the journal about the voyage of *Fram*, the Captain commented that, "the first week was quiet on board, as owing to the circumstances, there was no communication with the shore..." (Nilsen, in Amundsen 1912, p. 220).

On the next day, Friday 8 March, a long telegram was sent to his financial supporters at the *Daily Chronicle*. It is unclear if Amundsen, Lieutenant Prestrud or Captain Nilsen sent it – the latter two had good English and may have translated it from Norwegian. Next, according to Jack Cato, Amundsen went to the studio of Hobart photographer, J.W. Beattie, where he engaged Beattie to develop his glass negatives of the polar expedition (Cato 1955, Ytreberg 2017). Cato, a professional photographer, was Beattie's cousin and living in Hobart at the time. Beattie therefore, or his assistant Searle, was probably the first person in the world other than the Norwegian polar party, to see a photograph of the South Pole.

During the evening of Friday 8 March, telegrams began to pour in as the world realised that Amundsen had won the 'Race to the Pole'. The next day, Saturday, *The Mercury* reprinted the *Daily Chronicle* article with the heading *AMUNDSEN REACHES SOUTH POLE* (*The Mercury* 9 March 1912, p. 511, March 1912, p. 5).

On the following Monday (11 March), Amundsen dined with James Macfarlane (1844–1914) – the agent and consul for the Norwegian Government – at his home in New Town. This was a private if rather formal affair, with representatives from the Royal Society of Tasmania and the State Government, as well as consuls from the United States, Germany, the Netherlands, France and Sweden. Macfarlane, an Australian Senator from Tasmania (1901–1910), and his brother were the owners of a successful shipping firm, and James was a Fellow of the Royal Geographical Society and the Norwegian Consul for Tasmania. (*The Mercury* 12 March 1912, p. 4, Rydon 2000).

However, some local citizens were concerned that Amundsen had not been given an official, public welcome. At a meeting of the Tourist Association on Monday 18 March, Philp Samuel Seager urged authorities to hold such a welcome (*The Mercury* 19 March 1912, p. 8). The next day *The Mercury* went further by suggesting that the Hobart City Council had not organised anything because they were waiting for the State Government to do so and that the government had not done anything because it was assumed that the Hobart Council would. Nothing ever eventuated from either authority! (*The Mercury* 20 March 1912, p. 5). At least one Hobartian felt the same way. Margaret Thorp commented in her diary that "Hobart gave Amundsen a very poor reception on the whole" (Australian National Maritime Museum 2017). However, it must be said that during much of Amundsen's visit to Hobart, Premier Lewis was in Balfour on Tasmania's west coast.

Ten days after he had arrived in Hobart, on Monday 18 March, Amundsen was, however, invited to attend a meeting of the Royal Society of Tasmania. Amundsen was welcomed and, in his reply, he referred to both the former Lt. Governor of Van Diemen's Land, John Franklin, and to Captain James Clark Ross, the British explorer of the Antarctic, as two individuals who had inspired

PLATE 3 — Amundsen (second row, round hat) and his crew aboard the *Fram* while docked in Hobart, 14 March 1912. (Photo: Open Access Tasmanian Archives PH40–1–337(1))

him. He also, diplomatically, mentioned Captain Scott commenting that he was not sure if he (Amundsen) had been the first to the South Pole and that it would be better to wait a while and hear what Scott had to say. He also wished Mawson every success. Referring to Hobart he said that it was a city with unique opportunities for exploration of the Antarctic. Further, Amundsen had noted that "the harbour of Hobart is an almost perfect one, large and remarkably well protected". The Acting Chairman of the Royal Society, Dr Fritz Noetling, congratulated Amundsen but regretted that the Governor was unwell (Royal Society of Tasmania 1912, *The Mercury* 19 Dec. 1912, p. 7).

At a meeting of the Tourist Association, Seager argued that "... I think it is a pity that some public recognition of Captain Amundsen's great work has not been taken in hand" (*The Mercury* 19 March 1912, p. 3). At a later Antarctic meeting at Her Majesty's Theatre on 25 June, the Anglican Bishop, John Edward Mercer, also commented that,

> *Hobart did not treat Captain Amundsen quite as well as it should have done when he arrived here after reaching the South Pole. We should have done more in the way of giving him a public welcome, and publicly congratulating him on his achievements, than we did. Hobart had a splendid chance of having its name bruited abroad, all over the world, as the place where Captain Amundsen was first welcomed after he returned from the South Pole, and it seemed to him a most regrettable thing that this chance should have been missed...*
> (*The Mercury* 26 June 1912, p. 6).

This issue requires more research to understand why there seemed to be an official reticence to publicly acknowledge Amundsen's achievement. Was it envy that the Norwegian succeeded where Scott presumably, had not? Was it, as *The Mercury* suggests, just inertia from the authorities? Was it a case of caution in championing the Norwegian explorer until the world had heard from Scott the Englishman?

Fram remained in Hobart for 13 days during which time Captain Nilsen reported that they repaired the propeller, cleaned the engine and spliced the broken top-sail yard (Nilsen in Amundsen, Volume II, 1912). She left Hobart on Wednesday 20 March for Buenos Aires. Amundsen himself travelled by train to Launceston and then took a steamer to Melbourne for his lecture tour through the mainland states. The arrival and presence of the Norwegian ship and crew had brought much attention to Hobart, its services and location. Hobartians had become familiar with the idea that their city could host and provide everything required for Antarctic expeditions. And yet Amundsen's visit was at the end of his journey not the start; the expeditioners were going home not heading for the Antarctic, they were, above all else, keen to return to Norway, and Amundsen was seeking opportunities to make public speeches on the mainland of Australia to larger audiences.

BARRIERS TO THE DEVELOPMENT OF HOBART AS AN ANTARCTIC CENTRE

When Amundsen appeared in Hobart in 1912 the so-called "Race to the Pole" was over and, as a result of World War I (1914–1918), nations did not have a period of peace in which they could promote science in the Antarctic. By then, European interest was largely focused on the more easily accessible Antarctic Peninsula not East Antarctica. These may have been among the reasons why the Norwegian Expedition did not create more excitement in Hobart and why they did not require all of the port and ancillary facilities that were potentially on offer. It was clear that there were other, significant, mostly external, obstacles to the complete establishment of an Antarctic gateway port in Hobart.

Whilst it may be tempting to regard Hobart's status as an Antarctic gateway being guaranteed because of the two Heroic Era expeditions led by Mawson and Amundsen, neither of them became the catalyst for Hobart to become a major Southern Ocean and Antarctic port. They did not go unnoticed, but they did not generate the sufficient impetus that one might have expected.

During the years that followed, the Tasmanian Government and society were consumed by dealing with disasters or focusing on industrial policies rather than in developing its natural advantages as a gateway for Antarctic and Southern Ocean exploration and science. Only a few months after Amundsen's visit, Tasmania was rocked by a massive fire at the Mount Lyell mine and then the ensuing Royal Commission into the disaster preoccupied the State Government (*The Mercury* 17 Oct. 1912, p. 5, Schultze 2011). The following summer of 1913 was hot and dry, and the vegetation on Mount Wellington was particularly vulnerable. A significant fire spread rapidly during the first week of March, and even in the Huon Valley farms and houses were destroyed (*The Mercury* 5 March 1913, p. 5). The government and its departments were occupied for many months in restoring services, repairing roads, bridges and houses. This was also a period in Tasmanian history when the government pioneered hydroelectric generation as a way of powering new industries and providing electricity to houses, farms and businesses across the island. By 1914 the Lake Margaret Power Station was commissioned and construction work had begun on the Waddamana Dam taking two years to complete (Mathers 2010).

The government also had to contend with the outbreak of World War I. With great initial enthusiasm, Tasmania's war effort began well with healthy numbers of volunteers, many patriotic funds developed and public support for the war running strongly. However, the government was kept pre-occupied for the duration of the war dealing with a range of issues: the imprisonment of enemy aliens, trying to solve high levels of unemployment and attending to the increased frequency of industrial disputes (Henning 2006). There was also widespread doubt about, and opposition to, Australia's participation in World War I especially in response to the divisive conscription campaigns. Marilyn Lake suggested that the opposition and disillusionment

of the Tasmanian community have largely gone unheeded in official accounts of the war (Lake 1975, pp. 44–63).

Even after the war the government was preparing for, and spending on, the development of both the Electrolytic Zinc Company and the Cadbury companies. Despite some potential to improve port facilities, neither of these new industries required any significant plans for improving Hobart's port to better accommodate ships or expeditions bound for the Antarctic and Southern Ocean. The government was in no situation to encourage or enhance new building works for the port in Hobart, nor was there a nation seriously interested in making use of such facilities for exploration and science in the Southern Ocean or Antarctica. Neither the arrival of Norwegian whalers during 1923 nor, significantly, the visit of the British Australian and New Zealand Antarctic Research Expedition (BANZARE) in 1930, prior to their second voyage, could give the port a renewed sense of purpose (Hudspeth & Scripps 2000, pp. 172–173).

The Great Depression hit the Tasmanian economy seriously in part because, despite the emergence of industries in the 1920s, Tasmania was already poorer than the mainland, and the Depression had a devastating impact – in 1931, 27% of workers were unemployed. Loss of employment occurred in many areas in the private and public sectors, and many workers were put on reduced time (Cloudsdale 2006). More serious bushfires in 1934 had slowed financial recovery. It was not until after the road to the summit of Mt Wellington had been completed, and a new government elected with a more Keynesian approach, that Tasmania began to return to a reasonable financial position (Tasmanian Year Book 2000, Cloudsdale 2006). Even then, it was not until well into World War II that the government was able to run a budget in the black when the state's industrial base was required for the allied war effort. World War II (1939–1945) put a stop to most Antarctic exploration for most nations apart from Germany, which in the pre-war phase, had claimed New Swabia, near Queen Maud Land for the Third Reich (Lüdecke & Summerhayes 2012).

Not until after World War II were nations again able and interested to explore Antarctica. It can be argued that Hobart did not really develop as an Antarctic gateway until well after World War II, and there appears to have been three significant steps in this process. First was the setting up of the Australian National Antarctic Research Expeditions (ANARE) in 1947; the second was the construction of Australian science research stations in the Antarctic and the third was the relocation of the Australian Antarctic Division headquarters to Hobart in 1981. None of these steps occurred until after World War II when increasing pressure of Cold War tensions drove the United States of America and the Soviet Union as well as Australia, to regard Antarctica as a potential territory of scientific and economic development potential. The conclusion of this process was to boost Hobart's capacity as a hub for Antarctic activity (Bowden 1997, Allen 2006). Although there was cooperation between nations during the International Geophysical Year 1957/1958, in which Australia played a significant role (Australian Antarctic Program), in the period from 1912 to the late 1980s, there were, nevertheless, many barriers that prevented the port and the city of Hobart from becoming major players in this Antarctic activity. However, since the 1980s Hobart has come to be seen as an Antarctic gateway, the equal of Christchurch, Cape Town, Punta Arenas and Ushuaia. Australia's federal and state governments and Hobart City Council have been proactive in developing and maintaining facilities that extend Hobart's ability to assist expedition ships and crew, and act as a centre for Antarctic science, management and logistics (Tasmanian Antarctic Gateway Strategy https://www.antarctic.tas.gov.au/about/gateway_infrastructure, Department of State Growth 2020, Tasmanian Polar Network https://tasmanianpolarnetwork.com.au/).

CONCLUSION

Successive nineteenth-century expeditions into the Southern Ocean had found that the port of Hobart was convenient in terms of its location and that it could provide the services required by ships and expeditioners heading into the high southern latitudes. Two of the most significant expeditions during the "Heroic Era" had also utilised the port of Hobart's facilities and it was well thought of as a gateway to the south. Nevertheless, even the momentum built by these two major expeditions was not sufficient impetus for Hobart to become a major base for activity in our region of Antarctica. Mawson's AAE was important for the new nation of Australia, but our activity in the south was not focused on Hobart until the 1980s. In addition, even though Amundsen's Norwegian expedition was an internationally important victory, in itself it did not create the conditions to establish Hobart as the significant southern port for exploration into the Southern Ocean or Antarctica. In fact, exploration on its own was not the major factor for the development of Hobart as Australia's Antarctic gateway: it was a combination of international cooperation in science, the renewed focus on Antarctica after World War II, and the Australian government's recognition of Hobart as the national link to the south, that finally made Hobart the global science and research hub for Antarctica that it is today.

ACKNOWLEDGEMENTS

My sincere thanks go to Dr Anna Lucas and Dr Lorne Kriwoken who initiated and inspired this paper and the two referees for their helpful comments and suggestions.

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(accepted 18 October 2022)

THE INVERTEBRATE FAUNA OF THE STONY HEAD AREA, TASMANIA, AUSTRALIA: FINDINGS FROM AN INTENSIVE SURVEY, SUMMER 2020–21

by Simon J. Grove, Catherine J. Byrne, Lynne G. Forster, Kevin J. Bonham, Simon Fearn, John Douglas, David Maynard and Arlee McMah

(with one text-figure, twelve plates and one appendix)

Grove, S.J., Byrne, C.J., Forster, L.G., Bonham, K.J., Fearn, S., Douglas, J., Maynard, D., Rainbird, J. & McMah, A. 2022. (i:xii): Invertebrate fauna of the Stony Head Area, Tasmania, Australia: findings from an intensive survey, summer 2020–21. *Papers and Proceedings of the Royal Society of Tasmania* 156: 121–133. ISSN 0080-4703. Tasmanian Museum & Art Gallery, GPO Box 1164, Hobart, Tasmania 7001, Australia (SJG*, CJB, LGF, KJB); Queen Victoria Museum & Art Gallery, 2 Wellington Street, Launceston, Tasmania 7250, Australia (SF, JD); 13 Hayley Court, Deviot, Tasmania 7275, Australia (DM); Evolution & Ecology Research Centre, School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, New South Wales 2052, Australia (AM). *Author for correspondence. Email: simon.grove@tmag.tas.gov.au

An invertebrate fauna survey of the Stony Head Military Training Area in northern Tasmania was conducted over the period November 2020 to March 2021 as part of Australia's Bush Blitz program. The survey focused on insects, spiders and molluscs, with other taxa sampled opportunistically, and identified numerous species that are noteworthy for their apparent rarity, habitat specificity or biogeographical interest. This paper documents the key invertebrate habitats during this survey and some of their associated species, including their ecological roles and likely management needs.
Key Words: invertebrate biodiversity, insects, spiders, molluscs, Stony Head, Tasmania.

INTRODUCTION

Bush Blitz is a national partnership program that organises expeditions to document Australia's flora and fauna and to facilitate the discovery of new species (https://bushblitz.org.au/). The invertebrate fauna survey of the Stony Head Military Training Area, in northern Tasmania, was conducted over the period November 2020 to March 2021. Details of this expedition including information on the property's predominant vegetation types, summary tables on threatened species, introduced species, putative new species and taxonomic lists of all the species recorded, are provided in Bush Blitz (2022).

Commensurate with its bioregional context, Stony Head features a diverse range of vegetation (fig. 1) and habitat types including dry eucalypt woodland, wet eucalypt woodland, coastal *Allocasuarina* woodland, coastal scrub, coastal heaths, grasslands, dunes, beaches and ephemeral wetlands. In this paper we document some of these key habitats and other resources at Stony Head and highlight the associated invertebrate species recorded, selected for their apparent rarity, habitat specificity or biogeographical interest. Additionally, we briefly consider their ecological roles and management needs.

METHODS

Prior to the main expedition in March 2021, several preliminary visits were made. An initial reconnaissance visit (by SJG, SF & DM) occurred on 2 to 5 November 2020 during which some opportunistic hand collection of terrestrial invertebrates was undertaken as well as pond-dipping at the brackish lagoon to the northeast of Fothers Hill. Malaise traps – tent-like flight intercept traps (pl. 1) – were established at four locations on the property at this time, including two that would later become standard survey sites during the main expedition. We used a combination of "Townes"-style and "SLAM"-style traps. These sampled continuously, with a service and bottle changeover (by SJG) on 30 November, until their removal on 4 January 2021 (by SJG). A *LepiLed* LED UV light trap (Brehm 2017) was operated (by SJG) near the base camp on the night of the 30 November visit, at which time some opportunistic hand collection was also carried out. Appendix 1 lists some of the placenames visited or otherwise referred to in this paper; however, collecting was not confined to these locations but extended across the entire property and amounted to 67 distinct sample sites, chiefly along roads, tracks and the coastal fringe.

The main expedition took place between 15 and 23 March 2021. Two Malaise traps were reinstated during the expedition, sampling from 15 to 22 March at the two chosen standard survey sites. Arrays of eight dry pitfall traps (plastic cups) and six pan traps (plastic picnic bowls – two yellow, two white and two blue, charged with water and detergent) were also installed at these same sites; these sampled continuously from 16 to 23 March, and then removed. Bucket black-light traps and/or *LepiLed* LED UV lights and/or MV lights were operated nightly at various localities across the property, with different areas being chosen on successive nights, among them the two standard survey sites (Appendix 1).

Our individual areas of focus were broadly: land snails, slugs and non-arthropod terrestrial invertebrates (KJB), spiders (JD, LGF), heteropteran bugs (AM), moths (CJB,

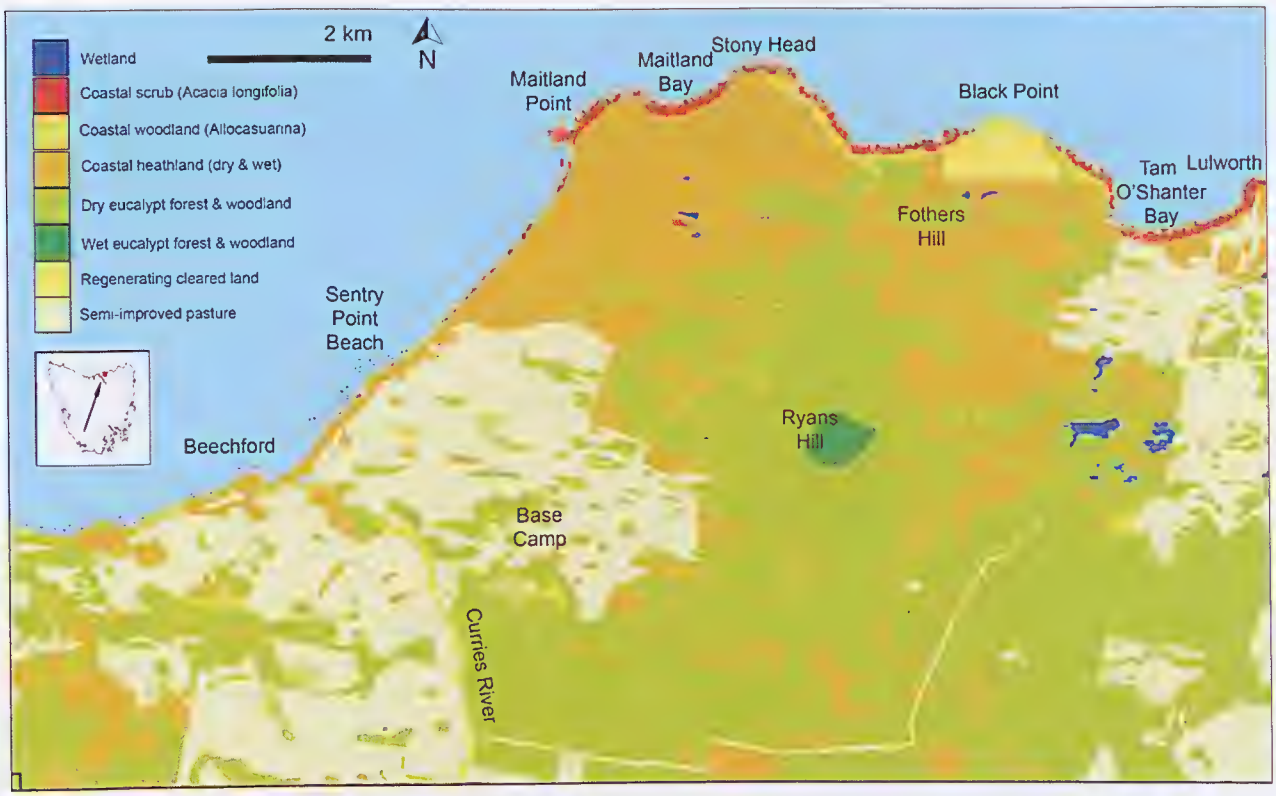

FIGURE 1 — The main vegetation types at Stony Head based on TASVEG 4 Groups, a 2020 compilation by the Tasmanian Vegetation Monitoring and Mapping Program at Natural Resources and Environment, Tasmania. Mapping is indicative only, and category names have been modified for this paper.

SF) and insects more generally (SJG, SF, LGF, DM). Other taxa, such as non-marine crustaceans, were collected opportunistically and identified with the help of colleagues in the Australian taxonomic community.

Active collecting techniques employed across the property during the March expedition included sweep-netting, beating, log-rolling, stone-turning, bark-peeling, litter sifting, sand-sifting, knockdown pyrethrum spraying of grasstrees and bark, dip-netting, general hand searching, and vehicle vibration (Raven 2019). This last technique (pl. 2) involved parking the diesel vehicle on a track running through the target habitat and leaving the engine operating for about 20 minutes, during which time the vibrations passing through the ground nearby would cause ground-dwelling invertebrates – spiders, insects, scorpions, centipedes, slaters etc. – to wander towards the source of the disturbance and out into the open, where they could be more readily observed and collected.

Active collecting was largely confined to the available tracks that bisected the property. Some off-track collecting took place on the slopes of Fothers Hill and Ryans Hill, as well as along the coastal fringe, including rocky headlands (Black Point, Stony Head, Maitland Point) and sandy shorelines (Maitland Bay, Sentry Point Beach) and their immediate hinterland. Collecting sites across a range of habitats are shown in plates 1, 2, 3 and 4.

Collected specimens are now held in the host institutions of the participating zoologists, with the vast majority being registered into the collections of the Tasmanian Museum and Art Gallery, Hobart, and the Queen Victoria Museum and Art Gallery, Launceston. The associated electronic records are being made available online through the *Atlas of Living Australia* https://www.ala.org.au/ and, in due course, the Tasmanian Government's *Natural Values Atlas* https://www.naturalvaluesatlas.tas.gov.au/.

RESULTS

A list of the invertebrates identified at Stony Head is documented in the Bush Blitz expedition report (Bush Blitz 2022). This comprises well over 1500 insect species, over 120 spider species, and 21 land-snails and slugs; about 33 species are introduced, and at least 41 (24 of them spiders) are likely to be undescribed species. A sizeable proportion of the listed taxa remain unidentified at the species level. Many of our Stony Head records represent significant infills in the species' known ranges, or significant range extensions, including about 20 that are the first known records for mainland Tasmania – although two were previously known from islands in the Bass Strait.

These statistics are necessarily conservative. Complete inventories of insects, spiders or other species-rich invertebrate groups collected from Stony Head are practically unattainable – even with multiple sampling techniques and the resources of many experts. We often don't know enough about the ranges of described Tasmanian or Australian invertebrates to determine whether records represent significant range extensions or infills. The *Atlas of Living Australia* aggregates museum collections and

PLATE 1 — One of four Malaise traps used to sample flying insects. This one was near the summit of Ryans Hill. (Photo: Simon Grove, TMAG)

PLATE 2 — Sampling ground-living invertebrates using the "vehicle vibration" technique, in dry *Eucalyptus obliqua* woodland on Ryans Hill. (Photo: Simon Grove, TMAG)

PLATE 3 — The western coastal fringe of the property, showing sandy beach, dunes, coastal scrub and a rocky headland, with recently burnt coastal heathland in the foreground. (Photo: David Hocking, TMAG)

PLATE 4 — Sampling insects during November in dry, open heathland near Fothers Hill, among grasstrees *Xanthorrhoea australis* flowering after the 2021 bushfire. (Photo: Simon Grove, TMAG)

observational data and is a useful "first pass" for assessing whether new finds are suggestive of range extensions but must be used with caution since no museum collection is fully digitised, and the validity of observational records is often questionable. However, taxa not identified to species level, either because of lack of relevant expertise or because they are undescribed, cannot even be assessed in this regard. Additionally, vast numbers of specimens – chiefly smaller flies and parasitic wasps – have yet to be extracted from their Malaise or other trap samples and will, for the foreseeable future, remain unsorted in museums' "bulk samples" collections, awaiting the attention of future taxonomic experts. Whilst the existence of Bush Blitz bulk samples is discoverable through the "Tasmanian Museum and Art Gallery Bulk Samples Collection" on the *Atlas of Living Australia*, their taxonomic composition is not. For these reasons, the findings presented here are through the lens of the key invertebrate habitats at Stony Head, and the varied ecological roles and management needs of some of the constituent species.

A plant list and brief description of vegetation of Stony Head is contained in Bush Blitz (2022). While some broad invertebrate habitats equate to vegetation types, their microhabitats are often as much about vegetation structure as floristic composition or may chiefly comprise non-vegetation-based elements such as bare ground, dung or carrion. Here we describe broad vegetation types only, and as an aid to local species assemblages, the names of species are followed in parentheses by their relevant family name and accepted common names for species are in capitals.

THE COASTAL FRINGE

The Stony Head property encompasses a range of shoreline types, notably sandy beaches and adjacent low, rocky cliffs (pl. 3). The northern coastline features boulders and depending on aspect and exposure, the shoreline is backed by dunes, coastal scrub or woodland. Each habitat supports characteristic assemblages of invertebrates.

Sandy beaches, dunes and *Acacia longifolia* coastal scrub

Sandy beaches and dunes represent a unique environment for terrestrial insects and support a range of species found nowhere else (Grove & Forster 2019). The most "marine" of these is the weevil *Aphela algarum* (Curculionidae), that emerges at night from wet sand, probably to feed on stranded kelp. Only a single species of kelp-fly, the widespread *Chaetocoelopa sydneyensis* (Coelopidae), was identified, perhaps because the waters off the northern Tasmanian coast, unlike those elsewhere, tend to host more seagrass than kelp; kelp-fly larvae typically feed among the decomposing heaps of beached kelp. Also present was a rove-beetle predator of kelp-fly larvae, *Cafius sabulosus* (Staphylinidae). The husk of a Globefish *Diodon nicthemerus* on the strandline was being scavenged by a beach-specific darkling-beetle, *Scymena amphibia* (Tenebrionidae), which could be the first evidence of the species' occurrence in Tasmania in about a century. Its more widespread beach-specific congener, *Sphargeris physodes* (Tenebrionidae), another scavenger of dead marine life, was also found.

Further up the shore, above the strandline, a richer fauna prevailed. On the open sand, adults of several diurnal fly species were active. These included two beach-specific stiletto-fly species, *Anabarhynchus fuscoapicatus* and *A. maritimus* (Therevidae); their larvae live in the sand and predate other invertebrates. The same is probably the case for the beach-dwelling marchfly *Cystidomorpha vetusta* (Tabanidae). This species and two other predatory beach-dwelling flies, the muscid *Lispe cana* (Muscidae) and the dance-fly *Thinempis turimetta* (Empididae) were also collected. The riparian earwig *Labidura riparia* (Labiduridae) was found under driftwood, which also sheltered the beach wolf-spider *Tetralycosa oraria* (Lycosidae); both are widespread and commonly encountered species in this habitat.

Sifting sand at the very base of the seaward dunes revealed several specialist beetle species, including *Phycosecis litoralis* (Phycosecidae), *Lagrioida australis* and *Mecynotarsus leai* (Anthicidae) and the darkling-beetle *Hyocis bakewelli* (Tenebrionidae), all of which are largely nocturnal scavengers of dead arthropods. Also detected was the weevil *Pseudotimareta subterranea* (Curculionidae), whose larvae are likely to feed on the roots of dune grasses, including Marram *Ammophila arenaria* which was introduced to Tasmania to stabilise dunes. The False Blister-beetle *Copidita maritima* (Oedemeridae), a species whose larvae develop within driftwood, was found on flowers of non-native Sea Kale *Cakile maritima*. Sifting the sand around the base of Sea Kale produced many specimens of the Sea-kale Flea-Beetle *Psylliodes marcida* (Chrysomelidae) (pl. 5), a host-specific herbivorous species from Europe which has only recently been detected in Tasmania (its only known Southern Hemisphere outpost), though is now likely to be widespread around the Tasmanian coastline. Several Chequered Blue Butterflies *Theclinesthes serpentatus* (Lycaenidae) were observed fluttering around Grey Saltbush *Atriplex cinerea* in this zone, as well as in Seaberry Saltbush *Rhagodia candolleana* slightly further inland; both plants are foodplants for their larvae. *Atriplex* is also one of the larval foodplants of Cotton Web-spinner Moth *Achyra affinitalis* (Crambidae), and small numbers of adults of this species came to light at two sites near the coast. This is a well-known migratory species, prone to outbreaks, and is possibly a vagrant in Tasmania (Hill 2013).

The dominant, open-habitat dolichoderine ants (Formicidae) in the foredunes on the property are *Iridomyrmex bicknelli* and *I. calvus*; these species prey on many of the local invertebrates. Also collected in this zone were the submissive formicine ant *Polyrhachis femorata*, which forages at night (Andersen *et al.* 2009), and the seed-harvesting ant *Notoncus hickmani*, a species that will also take nectar from flowers at night and is active throughout the year.

The longer-established dunes backing onto the sandy beaches hosted their own habitat specialists. The highlight was the darkling-beetle *Caediomorpha heteromera* (Tenebrionidae), for which our discovery, through sifting sand around the roots of plants, represents the only recently verified Tasmanian occurrence record, though it was recorded from the Hobart area a century ago. Also detected using this technique was the largely coastal, scavenger darkling-beetle *Adelium brevicorne* (Tenebrionidae), and a dead specimen of the uncommon and largely coastal predatory ground-beetle *Chlaenius australis* (Carabidae), a species with a metallic-green pronotum and greenish reflections around the rim of the elytra. The much larger predatory black ground-beetle *Scaraphites rotundipennis* (Carabidae) is a more widespread specialist species of this habitat detected at Stony Head; its stocky legs are well-suited for digging in loose sand. A characteristic fly of this habitat, *Apotropina ornatipennis* (Chloropidae), was also common; the flies signal to one another across the sand in a semaphore-like manner, employing the dark markings on their wings.

More vegetated sections of dunes hosted further specialists. The very large Crusader Bug *Mictis profana* (Coreidae), named for the pale, cross-like markings across its wing-cases, was widespread around the coastal fringes of Stony Head. It may be a recent colonist of Tasmania, currently confined to stretches of the north and northwest coast, where it feeds on Coast Wattle *Acacia longifolia*. The Wattle-pig Weevil *Leptopius duponti* (Curculionidae), a large black weevil with knobbly wing-cases, is another Coast Wattle associate found widely on the property; its larvae feed on the plants' roots. Honeydew produced by the treehopper *Sextius* species, probably *S. virescens* (Membracidae), through its feeding on the sap of Coast Wattle attracted ants (Formicidae), including the dominant *Iridomyrmex bicknelli* and solitary foraging Jack Jumpers *Myrmecia pilosula*. The lauxaniid fly *Steganopsis melanogaster* (Lauxaniidae), a species which in Tasmania is apparently confined to the far northeast, and the sand-wasp *Podalonia tydei*, a widespread predator of caterpillars in sandy country, were also present.

Two unexpected land-snail finds, *Tornatellinops jacksonensis* (Achatinellidae) and *Omegapilla australis*

(Pupillidae), occurred alongside other species more normally encountered in vegetated dunes. The record of *T. jacksonensis* is the first from the Tasmanian mainland, and only the fifth record from the state; the species may possibly be adventive, and if so, probably pre-European. The record of *O. australis* is the first from the northern Tasmanian coast, though the species is common on the east coast and on islands in eastern Bass Strait.

The darkling-beetle *Gonocephalum* cf *elderi* (Tenebrionidae) was found on one of the rocky headlands close to a sandy shore. It had not previously been recognised from Tasmania before, although newly identified specimens in the TMAG collections indicate that it has a wider distribution in sandy, mostly coastal, country in northern and eastern Tasmania. The tiny, bristly millipede *Phryssonotus australis* (Polyxenidae) (pl. 6), a rarely seen species but not uncommon in warm, dry microhabitats, was also found here.

Coastal woodland including *Allocasuarina*-dominated vegetation

Along rocky sections of coastline, woodland of *Allocasuarina littoralis* and *Pomaderris apetala* predominates. Much of it has been recently burnt, but unburnt areas remain and support a few characteristic invertebrate species. Most noteworthy is the coarse-ribbed carnivorous snail *Tasmaphena ruga* (Rhytididae). Although widespread inland, this is the first record of the species from the north coast of Tasmania. *Allocasuarina*-feeding insects found at Stony Head include the lace-bug *Epimixia allocasuarina* (Tingidae), the mirid bug *Ommatodema leanum* (Miridae), the weevil *Haplonyx casuarinae* (Curculionidae) and the moth *Rhynchopsota delogramma* (Geometridae). All are cryptically patterned to ensure they remain hidden when at rest or feeding on the "needles" of their host plant. *Pomaderris apetala* is a food plant of the moth *Casbia melanops* (Geometridae), which was recorded at several sites.

DRY (COASTAL) HEATHLAND

Though classified as coastal, the dry heathlands at Stony Head extend well inland. Dry heathlands are rich habitats for insects and spiders. While some insects are associated with particular plant species, habitat structure – of the constituent plants, or indeed of the gaps between them – can be equally important for insects and arguably more so for spiders. The heathlands at Stony Head experience a level of disturbance – chiefly from tracked vehicles – that increased the array of microhabitats present. Periodic fires can appear destructive – our visit coincided with the aftermath of a severe fire the previous year that burnt through the heathlands towards the northern coastline – but at the "right" frequency and intensity, they too help to maintain favourable, open heathland conditions.

Tracks, fire breaks and other areas of open, disturbed ground

The grasses and sedges which colonise the edges of tracks, and occur patchily in heathlands, are key habitats for many insects and spiders, which depend on them either for food or for habitat structure. At Stony Head, many elements of the rich grasshopper fauna occur in these track habitats. The Australian Plague Locust *Chortoicetes terminifera* (Acrididae) was quite common in this habitat, suggesting that it may now be resident in this part of Tasmania, though past Tasmanian records would seem to represent individuals dispersing across Bass Strait during sporadic population eruptions on the mainland (DAFF 2021). The Yellow-winged Locust *Gastrimargus musicus* (Acrididae) was also common. Two small orthopterans, the grasshopper *Austroicetes pusilla* (Acrididae), found along a coastal track, and the pygmy-cricket *Trigonidium canberrae* (Trigonidiidae), found on tracks through the heathland, are otherwise known in Tasmania from one or two records each from the northwest. Rare or under-recorded orthopterans include the grasshoppers *Exarna includens* (Acrididae) and *Vandiemenella viatica* (Morabidae), found in similar habitat; and the widespread Tasmanian endemic bush-cricket, *Coptaspis lateralis* (Tettigoniidae), which was locally common.

Bare ground

Many insects and spiders require bare ground, some for nesting, others for basking or foraging. The heathland at Stony Head, which was recovering from a fire the previous year, yielded ground-nesting wasps and bees, predominantly *Lasioglossum* species (Halictidae), but they remain unidentified to species. One indicator of a rich bee and wasp fauna is the diversity of velvet-ant (Mutillidae) species, since their larvae live as parasitoids, feeding on the broods of non-social bees and wasps. Velvet-ant females are flightless and resemble stout ants. Four were identified to species-level: *Ephutomorpha amoenula*, *E. cordatiformis*, *E. lateralis* and *E. subcristata*; several additional unidentified and potentially undescribed species were also collected. Other parasitoids of bees and wasps found in the heathland include the bee-fly *Meomyia fasciculata* (Bombyliidae), whose larvae initially feed on the food stores of solitary bees; the conopid fly *Microconops tasmaniensis* (Conopidae), which lays its eggs directly on the adult bee; the flesh-fly *Protomiltogramma laticeps* (Sarcophagidae), which lays live larvae in the nests of solitary bees; and the blister-beetle *Palaestra cyanipennis* (Meloidae), whose larvae start out life by climbing up flower stems and hitching a ride back to the nest on a flower-visiting bee, to consume the bees' food stores and larvae. All these species are very local in Tasmania, favouring high-quality heathland habitats. The Bluebottle-ant *Diamma bicolor* (Thynnidae), whose larvae are parasitoids of Mole Crickets *Gryllotalpa australis*, was also present.

Three species of *Maratus* peacock spider (Salticidae) were recorded at Stony Head, generally from open areas with low grasses: *M. proszynskii*, *M. pavonis* and *M. plumosus*. The last

PLATE 5 — The Sea-kale Flea-beetle *Psylliodes marcida* (Chrysomelidae), a European species associated with Sea-rocket *Cakile maritima* and newly discovered in Tasmania. (Photo: Simon Grove, TMAG)

PLATE 6 — The millipede *Phryssonotus australis* (Polyxenidae), a species that favours much drier ground than most millipedes, found on rocky ground above Maitland Bay. (Photo: Simon Grove, TMAG)

PLATE 7 — An unidentified species of toad-bug *Nerthra* species, enticed to the ground surface using the "vehicle vibration" technique. (Photo: Simon Grove, TMAG)

PLATE 8 — Lichen moth *Asura cervicalis* (Erebidae). Only a single specimen of this common moth, whose larvae feed on arboreal lichens, was found during the survey. (Photo: Cathy Byrne, TMAG)

of these is a rather local species in Tasmania. The grasshopper *Cirphula pyrrhocnemis* (Acrididae), a characteristic species of warm, open heathland, was also present.

Grasstrees

Grasstrees *Xanthorrhoea australis* are a conspicuous and ecologically important component of the heathlands at Stony Head. When flowering, they attract a wide range of nectar- and pollen-feeding insects. Our November visit coincided with a post-fire flowering event (pl. 4), and many insects were present, including males of the large, black-and-yellow flower-wasp *Catocheilus apterus* (Thynnidae), whose larvae are parasitoids of the subterranean larvae of scarab beetles. Grasstrees are also the sole host-plant for the larvae of several insect species – the larvae being variously associated with the grasstrees' sappy exudates, their living flower or leaf tissues or the accumulations of dead tissue within the stems or at their base. During the November visit, such species included the large hoverfly *Orthoprosopa grisea* (Syrphidae), the dark-winged soldier fly *Octarthria brunnipennis* (Stratiomyidae) and the small lauxaniid fly *Paranomina longa* (Lauxaniidae). The latter species is in a genus generally associated with grasstrees and includes three species in Tasmania. However, *P. longa* – a Tasmanian endemic that was only recently described (McAlpine 2019) – is unusual in having also been recorded from sites lacking grasstrees, though at Stony Head it was only found in close association with these plants.

An unusual, beetle-like plant-bug *Carvalhoma malcomae* (Miridae) was collected from the decaying cortex of the plant, though whether this is its chief habitat remains unclear. Its discovery at Stony Head constitutes a new Tasmanian record for the species which is otherwise known from inland Victoria and NSW. Several specimens of the moth *Moerarchis australasiella* (Tineidae) were collected in the northern coastal heathlands; its caterpillars bore into the dead flower-spikes of grasstrees.

WET HEATHLAND AND *EUCALYPTUS OVATA* WOODLAND

At Stony Head, wet heathland forms a mosaic with drier heathland, and in places merges into patches of wet *Eucalyptus ovata* woodland or paperbark/tea-tree thickets. As with dry heathland, key habitats for invertebrates are often as much about structure, or moisture levels, as vegetation composition *per se*. For example, the toad-bug *Nerthra* species (Gelastocoridae) (pl. 7), whose adults live partly buried in periodically wet ground, and an uncommonly collected ground beetle, *Oodes modestus* (Carabidae) were some of several insect species that were collected using the "vehicle vibration" technique along one of the sandy tracks (pl. 2).

Webs from colonies of gregarious jewel spiders *Austracantha minax* (Araneidae) were frequently draped across gaps between rushes and low bushes in riparian habitat, heathland and grassland. In similar habitats, the larger, colourfully banded St Andrews Cross Spider *Argiope keyserlingi* (Araneidae) was present, alongside its cosmopolitan congener, *A. trifasciata*. The two species were sometimes observed sharing the same tussock, where their webs trapped large prey including butterflies and grasshoppers.

Several moth species that feed on *Leptospermum* were found in wet heathland, including *Porela subfasciata* (Lasiocampidae); the very abundant and widespread *Chlorocoma cadmaria* (Geometridae); and *Epicoma melanospila* (Notodontidae). The ornate, green and brown stinkbug *Cuspicona stenuella* (Pentatomidae) was well camouflaged on *Melaleuca*, its local foodplant.

Lichens

Lichen-feeding moths are an important part of the fauna at Stony Head, and are most prevalent where corticolous lichens are common, such as in the wetter, shadier and more mature wet heathland and woodland types. Many of these belong to the tribe Lithosiini (Erebidae). Of the 12 taxa from this tribe recorded here, little is known of their biology, but they are all likely to be lichen-feeders. Both local species of *Palaeosia*, *P. bicosta* and an undescribed species, were collected in heathland/woodland habitat. In this case, the caterpillars in this genus are known to be associated with lichens, and possibly mosses, growing on the branches of shrubs and trees. Similarly, *Asura cervicalis* (pl. 8) is a widespread species associated with lichens; a single specimen was recorded from a moist gully on the southwest perimeter of the property.

Brackish lagoon

A slightly saline lagoon inland from the north coast, set among recently burnt heathland and paperbark/tea-tree scrub below Fothers Hill, supported the rare clam-shrimp *Eulimnadia (Paralimnadia) rivolensis* (Limnadiidae). The species matures over winter and during the spring, and many adults were present when dip-netting on our November visit, but all had vanished by the March visit, by which time the water-level in the lagoon had lowered considerably. These predatory crustaceans are found widely but sparsely across Australia in their restricted habitat, both coastal and inland. Tasmanian records are few, and the only other recent record known to the taxonomic expert on this group is from Flinders Island (Timms 2019 and pers. comm. SJG). Fringing vegetation around the lagoon supported the uncommon planthopper *Thanatodictya* cf *hebe* (Dictyopharidae), while the groundhopper (grasshopper-relative) *Paratettix argillaceus* (Tetrigidae), a species that typically grazes on algal films, was found on adjacent bare, wet ground, along with a jumping-bug *Saldula* species (Saldidae).

Roadside ditches and ponds among wet heathland

While much of the Stony Head property is dry, the road network passes through some wetter areas, where roadside drainage ditches and ponds provide valuable aquatic and riparian habitat, including open water with emergent rushes and sedges. The local wetland/wet grassland grasshopper *Psednura pedestris* (Pyrgomorphidae), a slender species well-proportioned for life among the stems of rushes and sedges, was found around pond fringes. Dip-netting in some of the larger ponds revealed the presence of various predatory water-bugs and water-beetles, including the hand-sized needle-bug *Ranatra dispar* (Nepidae) (pl. 9), the water-bug *Naucoris congrex* (Naucoridae) and three large diving-beetles *Cybister tripunctatus*, *Hyderodes schuckardi* and *Onychohydrus scutellaris* (Dytiscidae). Adults of the latter species were observed emerging from their pupal cells in a mud bank and making their way to the water. All are widespread in such habitats, where tadpoles are likely to be important among their aquatic prey.

EUCALYPTUS AMYGDALINA FOREST AND WOODLAND

Heathy *Eucalyptus amygdalina* woodland is the most extensive vegetation type at Stony Head, and its insect fauna is probably typical of even larger areas of similar habitat elsewhere in Tasmania. The standout species is the bug *Baclozygum brachypterum* (Thaumastocoridae), which represents the first known record for this tiny, dorso-ventrally flattened, herbivorous species in Tasmania (and one of very few in Australia). Specimens were beaten or swept from low-hanging foliage of *Eucalyptus amygdalina*, and from nearby grasstrees. While this means that their preferred host plant is uncertain, the occurrence of the related *Baclozygum depressum* on eucalypts in northern Tasmania (Hill 1988) suggests a possible association with *E. amygdalina*. Also associated with this eucalypt at Stony Head is the weevil *Rhinotia bidentata* (Belidae). Two uncommon longhorn beetles (Cerambycidae) are an apparently undescribed species of *Strongylurus* longhorn beetle (Cerambycidae), which is known from fewer than ten specimens, and *Aphanosperma orientalis*, currently known from a few localities in the Tamar Valley and the far northeast of the

PLATE 9 — Needle-bug *Ranatra dispar* (Nepidae), caught by dip-netting in a trackside pond. (Photo: Simon Grove, TMAG)

PLATE 10 — Bark mantis *Paraoxypilus tasmaniensis*, a cryptic inhabitant of dry woodland. (Photo: Simon Grove, TMAG)

PLATE 11 — The stag-beetle *Lissotes launcestoni* (Lucanidae), found in rotting logs even in dry woodland. (Photo: Simon Grove, TMAG)

PLATE 12 — An unidentified velvet-worm *Ooperipatellus* species, found in a rotting log in a moist gulley on Barrows Hill. (Photo: Simon Grove, TMAG)

state. Longhorn-beetle larvae typically bore into wood, and the latter species is known to bore into the wood of *Persoonia levis* and *P. lanceolata* along the eastern seaboard of the Australian mainland (Webb 2020). The related *P. juniperina* is widespread in Tasmania and highly likely to be present on the property (M. Baker & M. de Salas, pers. comm. LGF).

Lacewings are poorly documented in Australia generally, but our record of *Psychobiella sordida* (Hemerobiidae) appears to be one of very few Tasmanian records.

Ants (Formicidae) of interest in the heathy woodland include two small relatives of the Jack Jumper, *Myrmecia fulvipes* and *M. urens*. In this habitat *Camponotus* ants forage for honeydew in trees at night to avoid competition from the day-active dominant dolichoderine ant *Iridomyrmex matiroloi*. Bugs of interest include an unidentified species of *Riptortus* (Alydidae), a herbivorous bug with thickened back legs which has only been found in a couple of other Tasmanian localities; the predatory assassin-bug *Coranus trabeatus* (Reduviidae) and the long-snouted, herbivorous lantern-bug *Rentinus dilatatus* (Fulgoridae) – the latter only ever light-trapped.

Flies of interest include the sap-run or rot-hole associated hoverfly *Cyphipelta rufocyanea* (Syrphidae); the blowfly *Stomorhina subapicalis* (Rhiniidae), the nocturnal scarab-killing fly *Cardiacera uniforma* (Pyrgotidae) – a parasitoid of adult scarab beetles, recorded from very few localities nationally, including only one other in Tasmania; and the lauxaniid fly *Trigonometopsis binotata* (Lauxaniidae) – another species with very few records nationally. Beetles of interest include the large, orange-and-black jewel-beetle *Temognatha mitchellii* (Buprestidae), whose larvae bore into the woody stems of *Allocasuarina* (a wing-case of this species was found on mud beside the brackish lagoon); the wasp-mimicking longhorn-beetle *Hesthesis plorator* (Cerambycidae), the scarab *Saulostomus villosus* (Scarabaeidae), and the minute hooded beetle *Periptyctus russulus* (Corylophidae) – a relative rarity.

The brightly coloured *Deliochus zelivira* (Araneidae) is one of the less common spiders recorded here.

EUCALYPTUS OBLIQUA DRY FOREST

For invertebrates, the distinction between the heathy woodland and dry forest is rather minor, other than the greater prevalence of larger trees and the under-bark and dead-wood habitats that they provide. Several beetles were found in association with dead or dying branches of eucalypts, sometimes by spotlighting at night, or in traps set nearby. These include the darkling-beetles *Olisthaena nitida*, *Zophophilus nigerrimus*, *Titaena columbina* and *T. tasmanica* (Tenebrionidae) and the zopherids *Docalis funerosa* and *Pycnomerus fuliginosus* (Zopheridae), the larvae of which feed on dead wood or dead bark; and the beetle *Ascetoderes taeniatus* (Bothrideridae). The last of these is probably a predator of wood-boring beetles and a possible rarity in Tasmania. Two ulodid beetles (Ulodidae), *Notocerastes tricornis* and *Meryx rugosa*, were found under eucalypt bark. Neither is common, and the first is apparently rare in Tasmania. Also under bark was an undescribed species of tube-dwelling spider in the genus *Gippsicola* (Segestriidae). Present in the dry forest is the bark mantis *Paraoxypilus tasmaniensis* (Amorphoscelidae) (pl. 10), which is not uncommon on tree-trunks in eastern Tasmania but readily overlooked because of its cryptic appearance; and an undescribed species of *Temnelytra* cockroach (Blattidae) otherwise known only from Launceston.

Ground-dwelling spiders collected in dry forest using the vehicle vibration technique include *Habronestes tasmaniensis* (Zodariidae), *Chenistonia trevallynia* (Nemesiidae), *Nyssus albopunctatus* and *Poecilipta zbigniewi* (both Corinnidae), an undescribed species of *Neostorena* (Zodariidae) and an undescribed species of *Argoctenus* (Miturgidae). The first two are Tasmanian endemics.

The moth fauna in eucalypt forest at Stony Head was dominated by large, eucalypt-feeding geometrids, most from the tribe Diptychini, with almost 20 species collected. A notable new record for the state was another large eucalypt-feeder, *Discophlebia lucasii* (Oenosandridae) – a family endemic to Australia. The gumleaf skeletoniser *Uraba lugens* (Nolidae), renowned for its damage to eucalypt plantations, was a common element here. The forests also supported a rich fauna of leaf-tying oecophorid moths (Oecophoridae), among which *Euchaetis parthenopa* was one of the most common and widespread. Six species of the large oecophorid genus *Garrha* were also collected in this habitat, including two undescribed species and the rare Tasmanian endemic, *G. miltopsara*. Caterpillars in this genus shelter in portable cases made by tying two dead eucalypt leaves together (Cocking *et al.* 2022). Another very common leaf-tyer, but of living leaves, was *Strepsicrates ejectana* (Tortricidae). Three species of *Abantiades* (Hepialidae), *A. hyalinatus*, *A. labyrinthicus* and *A. mcquillani*, were recorded across the site in low numbers. The long-lived caterpillars of these very large moths bore into the roots of eucalypts.

An undescribed snail in the genus *Tasmathera* (Charopidae) was found at four dry and one wet eucalypt forest sites in the south of the property. This species had been previously collected at two sites in the nearby Mount Direction area but was not recognised as apparently distinct from other undescribed species in the genus until specimens collected on this survey were examined.

EUCALYPTUS OBLIQUA WET FOREST

At Stony Head, wet (or damp) forest occurs as localised patches in gullies among drier forest and woodland, particularly on Ryans Hill. Since it comprises an uncommon habitat in the local context, its invertebrate fauna is similarly localised and therefore of particular interest. Leaf-litter and dead wood here retain more moisture than elsewhere, resulting in different, fungus-driven decomposition pathways that in turn influence the invertebrate fauna. Leaf-litter here hosts the tiny litterbug *Ceratocombus australiensis* (Ceratocombidae), while fungal fruiting-bodies attract the sun-flies *Tapeigaster nigricornis* and *T. paramonovi* (Heteromyzidae), whose larvae are fungivorous.

Several as-yet unidentified species of *Engynoma* lace-bug (Tingidae) were present on their food-plant, Silver Wattle *Acacia dealbata*, which occurs commonly in the wet forest as well as alongside some of the tracks. The Australian Variable Lacewing *Drepanacra binocula* (Hemerobiidae) also occurs in this habitat at Stony Head where it is likely to feed on psyllids associated with wattle trees. Ferns in the damp forest on Ryans Hill hosted the bug *Felisacus elegantulus* (Miridae), a species with very few reported records. In these damp habitats, ant (Formicidae) diversity is lower. *Anonychomyrma biconvexa* and *A. nitidiceps* replace *Iridomyrmex* species as the dominant dolichoderines and typically forage in trails on the ground and up tree trunks. Large Bull-ants *Myrmecia forficata* are solitary foragers, while small ponerine ants in the genus *Hypoponera* nest under logs and in ground litter.

Moth species that feed on *Acacia* were also prevalent in wet forests across the property. These include many species of geometrid moths (Geometridae), including the two Tasmanian satin moth species, *Thalaina selenaea* and *T. inscripta*; the widespread *Dissomorphia australiaria*; three species of *Scioglyptis*, only one of which, *Scioglyptis lyciaria*, is described; and the diminutive *Microdes villosata*. Granny Moth *Dasypodia selenophora* (Erebidae), a large and powerful migrant, was also collected at several sites. *Pararguda nasuta* (Lasiocampidae), whose larvae feed on *Acacia* as well as Native Cherry *Exocarpos cupressiformis*, was a common element in both wet and dry forests.

The larvae of crambid moths (Crambidae) in the subfamily Scopariinae are thought to feed on mosses and possibly lichens (Common 1990). Most species in this subfamily are referred to the genus *Scoparia*, of which seven species were collected here, mostly from moist gullies, all in very low numbers. Moths in the genus *Halone* (Erebidae) are also lichen-associated, but usually where the lichens grow on rocks or bare ground (Cocking *et al.* 2022). A few specimens of *Halone sejuncta* were collected at Stony Head, in the vicinity of damp gullies or other rocky areas.

Land-snail diversity in the wet forests was modest, with a total of 12 native species being recorded at forested sites. Many of the species were present at wet and dry forest sites,

though the carnivorous *Victaphanta lampra* (Rhytididae) was only found at wet and damp forest sites. The family Charopidae was under-represented, with only three forest-dwelling and one coastal species being recorded.

Rotting logs

Rotting logs of a sufficient size able to retain moisture through the summer are rare at Stony Head, but seemingly sufficient for some elements of the associated beetle fauna to survive. The stag-beetle *Lissotes launcestoni* (Lucanidae) (pl. 11) was found quite widely in this habitat, as was the flightless longhorn-beetle *Dorcadida bilocularis* (Cerambycidae) – most readily detected using the vehicle vibration technique. One recently fallen large tree hosted a colony of the bess-beetle *Pharochilus rugiceps* (Passalidae). This species is unusual in that the adults tend to their larvae, which lack the powerful jaws of the adults, by chewing wood and feeding it to them; family members also stridulate to stay in contact with one another. Other beetles of this habitat found at Stony Head include the jugular-horned beetle *Prostomis atkinsoni* (Prostomidae), a species that feeds on a scarce rotten-wood type known as mudguts; and the rotten wood-feeding darkling-beetles *Brycopia globicollis*, *Diemenoma commoda*, *D. tuberculifera*, and four species of *Adelium* (Tenebrionidae).

A single velvet-worm specimen, belonging to a species of *Ooperipatellus* (Peripatopsidae) (pl. 12), was found in a well-rotted damp log on Barrows Hill. Velvet-worms are sensitive to desiccation, and their presence at Stony Head is surprising and suggestive of a long continuity of wet-forest habitat in the area despite its fragmentary presence today. The same log also produced a large specimen of Westwood's Giant Centipede *Cormocephalus westwoodi*, as well as a miniature cave-cricket *Parvotettix* species (Raphidophoridae) and a terrestrial flatworm *Artioposthia* species (Geoplanidae) – both latter species are desiccation-sensitive.

MELALEUCA ERICIFOLIA SWAMP FOREST

Swamp forest among the heathland communities has been discussed previously. More uniform riparian thickets of *Melaleuca ericifolia* approaching the property's southern boundary weren't sampled in great detail but did produce the only specimen of the longhorn-beetle *Distichocera fuliginosa* (Cerambycidae) whose larvae may develop within the wood of this tree.

PASTURE

In this category we include the extensive areas of semi-improved pasture used seasonally for cattle grazing, along with two specific microhabitats – dung and carrion – that are commonly associated with pasture. Much of the pasture on the property seems to have been established through the clearance and drainage of wet heathland or wet woodland, since it contains ditches and soaks supporting wetland vegetation; it is likely that many areas of pasture flood seasonally. The large wolf-spider *Tasmanicosa subrufa* (Lycosidae) was found here, the burrows prominent in the sandy soil on slightly elevated ground. On lower-lying, damper ground, this species was largely replaced by a smaller wolf-spider *Artoriopsis expolita*.

The source of a distinctive cricket call, from the fringes of a wetland in the more agriculturally modified part of the property nearer to the farm, was *Lepidogryllus parvulus* (Gryllidae), representing the first confirmed record of this species from Tasmania (though a putative nymph of this species was found by SJG at Musselroe two years previously). Its calls were vastly outnumbered by those of Black Field-crickets *Teleogryllus commodus* (Gryllidae) and Pygmy-crickets *Bobilla bakali* (Trigonidiidae).

A rich fauna of crambid moths (Crambidae) occurred across the property, including eight species in the genus *Hednota*, one of which is undescribed. Many of these small to medium-sized, rather striking moth species feed on grasses and shelter in silk galleries in the crowns of grass or nearby soil. An exception is *H. bivitella*, whose caterpillars burrow into the soil beneath *Lomandra* (mat rush), on which they feed (Common 1990). These moths are recognisable for the longitudinal, often yellowish-brown stripes on their fore wings, offering good camouflage while resting on grass stems. *Hednota hoplitellus* is a new specimen-based record for Tasmania, otherwise only known from a 2019 observation at Binalong Bay (Atlas of Living Australia 2022). Another new record for the state known from only a single specimen, *Calamotropha leptogrammellus* or Grass Web-worm, is considered a pasture pest in other parts of Australia. Another common, grass-feeding crambid present at Stony Head was *Ptochostola microphaeellus*.

Adults of Southern Armyworm *Persectania ewingii* (Noctuidae), well known as a pasture pest in Tasmania, were extremely abundant during the survey, with large numbers of these moths coming to light traps every night. They are called armyworms because of the caterpillars' mass movements when present in plague numbers (McQuillan *et al.* 2007). The abundance of adults noted during our survey did not seem to correlate with a subsequent spring outbreak of caterpillars across the north of the state. Serious infestations are more usually caused by mass migrations of moths across Bass Strait, when favourable climatic conditions have allowed a build-up of populations in mainland source areas (Hill 2013). Another prominent pasture pest moth, *Philobota productella* (Oecophoridae), was found at one site. The caterpillars of this species conceal themselves in the soil during the day, to emerge at night to feed by cutting off grass leaves and dragging them back into their tunnels.

Three species of *Fraus* (Hepialidae) were recorded on the property. *Fraus simulans*, which can occasionally be abundant enough to be considered a pasture pest in Tasmania, was only recorded from a single specimen. Caterpillars of this species shelter in vertical tunnels during the day, emerging at night to feed mainly on grasses (Hardy

1973). *F. nanus* and a further, unidentified, *Fraus* species were also collected in low numbers.

Another common moth in the grasslands of the property was *Scopula rubraria* (Geometridae). This small, pinkish-tinged moth is noticeable because it is easily flushed from the undergrowth during the day and is also active at night. Its larvae feed on a wide variety of herbs.

Aquatic, semi-aquatic and riparian habitats within the pasture matrix

The extensive areas of rough grazing land are interspersed with old drainage ditches, some of which extend laterally into shallow wetlands and some deeper bogs. A single specimen of the Biting Snipe-fly *Spaniopsis clelandi* (Rhagionidae), apparently a new record for Tasmania, was swept from one of these ditch-lines; its larvae are aquatic. A Malaise trap set nearby caught the only specimen of the bog-associated hoverfly *Austalis pulchella* (Syrphidae), a metallic blue and gold species, which is more often encountered at higher altitudes where suitable bogs are more common. Its larvae are aquatic detritivores, living in or on organic sediments and breathing air through an extensible "snorkel" at their rear ends. The uncommon, rush-associated leaf-beetle *Eurispa albipennis* (Chrysomelidae) and the predatory damsel-bug *Nabis biformis* (Nabidae) were swept from drainage lines. Both are slender insects, able to camouflage their outlines against the thin stems of the rushes. The predatory ground-beetle *Notiobia rugosipennis* (Carabidae) – the first known Tasmanian record of this species – was collected near one of these drainage lines using the vehicle vibration method. The White Rush Moth *Tipanaea patulella* (Crambidae) was frequently observed by day flying among *Juncus* rushes, on which its larvae feed. The shiny, white wings of this moth are most likely good camouflage in damp environments where wet surfaces often catch the light.

Semi-improved pasture with wet hollows occurring immediately inland of the dunes along the property's western boundary provide further valuable habitat. The large grasshopper *Schizobothrus flavovittatus* (Acrididae) was common here. Specimens of the uncommon hoverfly *Sphaerophoria macrogaster* (Syrphidae) – a species currently known in Tasmania from only one other locality, in the southern Midlands – were swept from this habitat; the adults favour grasslands, where their larvae are predatory on aphids. Tasmania's only two species of snail-killing fly, *Dichetophora australis* and *Pherbellia juxtajavana* (Sciomyzidae), were also found here; their larvae are parasitoids of semi-aquatic snails, and both species are largely restricted to high-quality wetland fringes.

The unusual moth *Hygraula nitens* (Crambidae) was a common visitor to light traps across the property. This species belongs to the largely tropical subfamily Acentropinae, notable for the feeding habits of their larvae, which eat aquatic plants. Caterpillars of *H. nitens* live in slow-moving fresh or brackish water, whereas adults disperse widely and are often found long distances from water. A probable foodplant for this species, *Potamogeton cheesemanii*, was recorded from water bodies in the area (de Salas pers. comm. SJG). A less widespread member of this aquatic subfamily collected here was *Parapoynx euryscia*; little is known of its biology.

Dung

Grazing animals generate large quantities of dung, which provide opportunities for dung-recycling insects which are well-adapted to colonising this patchy resource. At Stony Head these include two exotic dung-beetle species, *Geotrupes spiniger* (Geotrupidae) and *Euoniticellus fulvus* (Scarabaeidae), which can process the dung of cattle, as well as four native dung-beetle species in the genus *Onthophagus* (Scarabaeidae), which are better adapted to macropod dung. All constitute widespread species, while a further introduced species, *Onthophagus binodis*, is more localised.

A rich fauna of marsupial scat-feeding moths in the family Oecophoridae was found on the property. The caterpillars of the majority of oecophorids utilise dead leaves as a food source (Common 1990), but some feed on pre-digested leaves in marsupial scats instead. These include *Oxythecta hieroglyphica*, which was widespread across the site, and the Tasmanian endemic, *O. nepheonota* and an undescribed *Oxythecta* species, both of which were scarce. *Oxythecta* species are generalist feeders on Brushtail Possum *Trichosurus vulpecula*, Common Wombat *Vombatus ursinus* and wallaby species scats. Members of two closely related genera were also present: *Scatochresis episema*, a widely distributed species complex in Australia, and two undescribed species of *Telanepsia*. Both genera are believed to be specialists on possum scats in Tasmania, although on the Australian mainland their larvae consume Koala *Phascolarctos cinereus* scats (Cocking *et al.* 2022).

Carrion

The carcasses of dead vertebrates represent a rich food-source for many insects, which fulfil the role of recyclers and the predators thereof (Grove & Forster 2020). The patchy occurrence of carcasses in space and time means that most of the associated insects have good powers of detection and dispersal, and many are representative of widespread, sometimes cosmopolitan, species. However, the full suite of species tends to only occur in higher-quality habitat supporting healthy populations of "source" vertebrates, such as at Stony Head. Dead wallabies and a dead cow were examined during the survey. Among the flies (Diptera), associated species recorded include one of the greenbottle flies *Chrysomya* species (Calliphoridae), the flesh-fly *Oxysarcodexia varia* (Sarcophagidae) and the signal-fly *Parapalaeosepsis plebeia* (Sepsidae), whose larvae feed on relatively fresh carrion; the black carrion-fly *Australophyra rostrata* (Muscidae), whose larvae are predatory on other fly larvae; and the introduced Cheese-skipper Fly *Piophila casei* (Piophilidae), whose larvae feed on bone marrow but emerge to pupate, "skipping" to more congenial pupation sites by curling their bodies into a c-shape and then rapidly flexing in the opposite direction. Their common name alludes to their ability to also colonise artisanal cheeses.

Recorded beetles include the carrion-beetle *Ptomaphila lacrymosa* (Silphidae), whose black, trilobite-like larvae feed communally on rotting flesh; ham-beetles *Necrobia ruficollis* and *N. rufipes* (Cleridae), whose larvae specialise in feeding on tougher, drier tissue; hide-beetle *Dermestes maculatus* (Dermestidae) and the trogid beetle *Omorgus australasiae* (Trogidae), both of which favour a diet of fur and skin; and hister-beetles *Saprinus cyaneus* and *S. laetus* (Histeridae), and the rove-beetles *Aleochara blackburni* and *Creophilus erythrocephalus* (Staphylindae), all of which are predatory on fly larvae.

DISCUSSION

Our surveys at Stony Head found a rich and varied invertebrate fauna, dependent on an equally rich and congruent set of vegetation types and other habitat features. Chief among these are wet and dry heathlands, woodlands, forests, seasonal and permanent wetlands, semi-improved grasslands, a network of open tracks and a largely undisturbed sandy and rocky coastline.

A number of records represent range extensions for species formerly known only from the Australian mainland. The presence of these is consistent with the climatic and biogeographic history of the Furneaux Bioregion, for which the Stony Head area is a geographical outlier: Stony Head comprises one of several outlier enclaves of the Furneaux Bioregion (Thackway & Cresswell 1995) that occur along the northern to northeastern coast of Tasmania, sharing similar geology, climate, landscape characteristics and vegetation communities with Flinders Island and Wilsons Promontory in Victoria. This lowland coastal bioregion is characterised as warm and subhumid, contrasting with the cooler and humid bioregions in more southern and western parts of Tasmania.

One notable influence is the Bassian land bridge that connected Tasmania with mainland Australia during an arid period in the last glacial maximum. At this time, the cold, dry and windy conditions would have favoured the dispersal of species adapted to grassy woodland and exposure to salt spray (Thomas & Kirkpatrick 1996, Adeleye *et al.* 2021). This influence may explain the occurrence of the clam-shrimp *Eulimnadia rivolensis* at Stony Head – although historically this species has also been found in saline lagoons in the Tasmanian Midlands and in brackish coastal lagoons in the south and east of the state. Among the darkling (tenebrionid) beetles, three genera in the xerophilic tribe Opatrini that have a "northern" distribution, extending from Australia into Asia (Matthews 2000), are rarely recorded in Tasmania, yet were represented at Stony Head in equivalently arid beach habitats by *Gonocephalum cf elderi*, *Caediomorpha heteromera* and *Scymena amphibia*.

Other species recorded from Stony Head that have affinities with mainland Australian distributions include species that have co-evolved with specific plants. For example, grasstrees host the moth *Moerarchis australasiella*, the bug *Carvalhomma malcolmae*, and the flies *Paranomina longa*, *Orthoprosopa grisea* and *Octarthria brunnipennis*. The Tasmanian host plants of some species, such as the bug *Baclozygum brachypterum*, beetle *Aphanosperma orientalis* and fly *Steganopsis melanogaster*, have not yet been verified and require future surveys. While we could predict their host plants, generalisations may not always be simple, as demonstrated by the fly *Paranomina longa*, whose association with grasstrees is seemingly not obligate (McAlpine 2019).

Refuges of wet sclerophyll forest and rotting logs supported invertebrates that reflect a different Gondwanan influence on their distribution. Several of these are endemic to Tasmania, such as the stag beetle *Lissotes launcestoni*, and, almost certainly, the unidentified velvet-worm and miniature cave-cricket. Many of the species found are common in wet sclerophyll forest across the state and are not restricted to the Furneaux Bioregion. Other wet-forest or Gondwanan elements were not detected, perhaps reflecting the small size of the refuges or their ecological history.

The invertebrate-habitat associations at Stony Head contribute to the modest body of knowledge concerning many species and reveal the co-existence of taxa with different evolutionary histories in a complex mosaic of habitat types. Many inferences about Tasmanian and mainland Australian species are limited by poor knowledge of distributions generally. The extent to which some of the species found during our survey are confined to the warmer sub-humid conditions that characterise the Furneaux Bioregion, or whether their presence represents a more recent southwards range expansion, is also unknown. Regardless, results from the eighth Tasmanian Bush Blitz in 11 years emphasise the high diversity of species yet to be discovered and the value of future surveys. Results underscore not only the value of the Bush Blitz program in accelerating species discovery, but also the vast amount of taxonomic work required following these expeditions and the urgency of learning more about the species' life histories and ecology.

What is also clear is that the fauna is, broadly speaking, the beneficiary of a relatively benign management regime at Stony Head, which has maintained a rich mosaic of functional habitats, in contrast to the losses to agricultural intensification and urbanisation experienced elsewhere in the region. As those losses intensify, the conservation value of Stony Head will only increase. We hope that maintaining these functional habitats will continue to be a priority for the property's managers. This would involve maintaining appropriate fire regimes for the different vegetation types, including deliberate, rotational burning in dry heathland and heathy woodland, and ensuring protection from fire in wet heathlands and wetlands; affording special protection to the brackish lagoon and other sensitive wetlands; maintaining strict hygiene standards to prevent the spread of Phytophthora root-rot (one of Australia's most harmful diseases for threatened species) into sensitive heathland habitat (especially stands of grasstrees); maintaining some rough grazing by cattle but keeping the use of pasture fertilisers and reseeding to a minimum, especially close to drainage lines; and continuing to minimise vehicle access to the property's beaches.

ACKNOWLEDGEMENTS

We thank the following: the Bush Blitz program and team for organising our expedition to Stony Head, particularly Kate Gillespie and Helen Cross for their work on the ground during the survey; the Department of Defence, and especially Dr Kate Hibbert and other Defence personnel present for their help and support during the survey, and for helping us select locations and guiding us in the field; Dr Kirrily Moore (TMAG) and Judy Rainbird (QVMAG) for fieldwork and field-lab support; Professor Brian Timms (Australian Museum/University of NSW) for confirming the identity of the clam-shrimp; and two anonymous reviewers for helpful comments on our submitted manuscript.

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(accepted 27 October 2022)

APPENDIX
Location of placenames referred to in the paper

Fothers Hill lagoon	40.9942°S x 147.0545°E
Standard survey site 1	41.0363°S x 147.0081°E
Standard survey site 2	40.9955°S x 147.0619°E
Base camp	41.0299°S x 146.9812°E
Farm wetland	41.0317°S x 146.9966°E
Fothers Hill ridgeline	40.9943°S x 147.0564°E
Ryans HIll	41.0171°S x 147.0279°E
Barrows Hill	41.0519°S x 147.0325°E
Black Point	40.9866°S x 147.0526°E
Stony Head	40.9818°S x 147.0193°E
Maitland Point	40.9843°S x 147.0016°E
Maitland Bay	40.9864°S x 147.0062°E
Sentry Point Beach	41.0153°S x 146.9617°E

LUMINOUS TASMANIA: SEEING THE DARK IN A DIFFERENT LIGHT

by Lisa-ann Gershwin

(with fourteen plates and two tables)

Gershwin, L. 2022(i:xii): Luminous Tasmania: seeing the dark in a different light. *Papers and Proceedings of the Royal Society of Tasmania.* 156: 135–160. ISSN: 0080–4703. Glow Show Tasmania, Studio 3, 71 Murray Street, Hobart, Tasmania 7000, Australia. Email: lisa@glowshowtas.com

A resplendence of poets could not conceive of something so exquisite as the kaleidoscope of nature's nocturnal glow. For the first time, this paper presents an overview of Tasmania's luminous phenomena: the Aurora Australis, or Southern Lights; Sea Sparkles, or marine bioluminescence *Noctiluca scintillans*; Glow-worms *Arachnocampa tasmaniensis*; Ghost Mushrooms *Omphalotus nidiformis* and other fungi; fluorescent scorpions *Cercophonius squama;* fluorescent marsupials (14 species), placental mammals (five species), and monotremes (two species); fluorescent birds (eight species); and Goblin's Gold Moss *Mittenia plumula.* For each, I briefly detail their natural history, early Tasmanian history, notes on their occurrence in nature, and other aspects of interest. Many of these phenomena are little known in Tasmania and require further scientific inquiry. All have great tourism and educational potential and most of the living forms are under increasing threat for their survival.
Key Words: bioluminescence, biofluorescence, Aurora Australis, Dinoflagellata, Diptera, fungi, Arachnida, Marsupialia, Aves, Tasmania, citizen science.

INTRODUCTION

Author Jennifer Tsang wrote:

> *"In the darkness of the night, bioluminescent insects or mushrooms reveal themselves, oceans light up when disturbed, and the world turns into a hauntingly beautiful place. One could imagine this sight as frightful or surreal, and bioluminescence may even resemble ghosts or spirits to some. Bioluminescence has held a folkloric charisma since ancient times."* (Tsang 2017)

Luminescence comes in many forms, but this paper covers only three: aurora fluorescence, biofluorescence and bioluminescence (the prefix *bio-* meaning made by organisms).

Bioluminescence is one of the oldest fields of scientific study, dating back to the first written records of the ancient Greeks. Its history and wonder are masterfully captured by Princeton Professor E. Newton Harvey's 700-page epic *A History of Luminescence from the Earliest Times until 1900* (Harvey 1957). Aristotle's *De Anima* is the oldest surviving detailed scientific treatment of bioluminescence, where he compared it to lightning "when you strike the sea with a rod by night and the water is seen to shine" (Harvey 1957, p. 40), and described it as "things that appear fiery or shining" (p. 66) and "exhalations of fire from the sea" (p. 41). Two millennia later, the Danish physician Bartholin wrote *De Luce Animalium* (Bartholin 1647), a comprehensive treatment describing every luminescent phenomenon known at the time (real or imagined). In Bartholin's view, light is innate and ubiquitous and should be regarded as a fifth principle or element (Harvey 1957).

Bioluminescence is a chemical reaction of two substances, a substrate called a luciferin, and an enzyme called a luciferase, which catalyses the oxidation of luciferin resulting in the emission of light. French pharmacologist Raphaël Dubois coined the terms luciferin and luciferase from his hot and cold experiments with glowing pastes made first from click beetles and then with clams (Dubois 1885, 1887).

In comparison to bioluminescence, biofluorescence is a completely different process, where an organism is illuminated by the light of one colour (e.g., invisible ultraviolet), which transforms it to another (often visible) colour (Murthy & Virk 2014). The term fluorescence was coined by Cambridge Professor Sir George Gabriel Stokes (1852), to describe what he called dispersive reflection, where the wavelengths of dispersed light are always longer than the wavelength of the original light (Valeur & Berberan-Santos 2011). Stokes repeated the experiments of Sir John Herschel with prisms and quinine. As he moved a test tube filled with quinine solution past the visible spectrum, the solution remained transparent, but in the invisible part of the spectrum corresponding to ultraviolet, the quinine glowed a beautiful celestial blue. Stokes wrote of his experience: "It was certainly a curious sight to see the tube instantaneously lighted up when plunged into the invisible rays: it was literally visible. Altogether the phenomenon had something of an unearthly appearance" (Valeur & Berberan-Santos 2011, p. 733).

Biofluorescence had, in fact, been known, but unnamed, since 1565, when the Spanish physician and botanist Nicolás Monardes observed and reported unusual colouration in medicinal herbs brought to Europe from the West Indies (Lagorio *et al.* 2015). However, for the next 500 years, bioluminescence stole the limelight and even then, most of the research on (or with) fluorescence

has been at the cellular or tissue level (Lawrence 1954). The concept of whole animals fluorescing in psychedelic colours has hitherto been restricted to a few obscure papers … and cartoons.

As mesmerising as bioluminescence and biofluorescence are, to many, the aurora is even more so. The Roman philosopher Seneca wrote: "There are Chasmata (chasms), too, when there is a subsidence of some portion of the heavens, which sends out hissing flame, as it were, from its hidden recesses. There are also a great number of colours in all these. Some are of brightest red, some of light insubstantial flame, some of white light, some glittering, some with a uniform glow or orange without sparks or rays" (Harvey 1957, p. 38). The aurora is produced by fluorescence, similar to biofluorescence but in outer space and on a much grander scale.

Luminous phenomena have fascinated mankind since time immemorial and are reported in the earliest and most conspicuous scientific and historical documents. For example, a cave painting of the aurora in France dates back 30 000 years to Cro-Magnon Man (NASA 2006). The Biblical prophet Ezekiel had a vision around 593 BCE (Siscoe *et al.* 2002): "And I looked, and, behold, a whirlwind came out of the north, a great cloud, and a fire infolding itself, and a brightness was about it, and out of the midst thereof as the colour of amber, out of the midst of the fire" (Ezekiel 1:4). Aristotle called the lights in the night sky "chasmata"; he, and Seneca 300–400 years later, thought cracks in the sky allowed light or flames to penetrate from beyond the heavenly firmament (Lummerzheim 2021). Aristotle likewise pondered bioluminescence, as did Pliny the Elder in the first century CE, both expressing wonder about its cool properties (Harvey 1957, Lee 2008). Christopher Columbus was captivated by bioluminescence around Bermuda on the second-last day of his famous voyage where he "discovered" the New World in 1492 (Geggel 2012). Captain James Cook is credited with making the first written scientific record of the Aurora Australis, observing it on the night of 17 February 1773 during his second voyage to Australia; although there is credible evidence that he and others observed it prior to that date (Willis *et al.* 2009). Darwin marvelled at bioluminescence in the Canary Islands during the *Voyage of the Beagle* (Darwin 1839), and yet was troubled by the discontinuous distribution of "phosphorescence" across taxa (Campbell 2012).

Historically, the term "phosphorescence" was used as a catch-all for different types of luminescence. Today, phosphorescence is generally taken to mean "slow luminescence", where the glow lingers after the excitation light ends, compared to fluorescence as "fast luminescence", where the glow disappears as soon as the source is removed (Princeton Instruments 2005). Both require stimulation with an external light source, such as a UV torch.

To study things today that glow in the dark is to study human curiosity, superstition and divinity. It seems particularly fitting, therefore, that the 2008 Nobel Prize in Chemistry was awarded for the discovery and development of Green Fluorescent Protein (Nobel Prize 2008), which has not only changed the landscape of medical research, but also given us a way to stop tripping over our pets at night. The study of "glowy things" spans physics, geology, chemistry, history and biology, as well as ecology, biodiversity and evolution, in outer space, inner space and subterranean under-space. It covers living organisms, dead organisms and non-organisms.

It may seem ambitious to synthesise a paper on eight entirely different fields of study, each topic with its own body of literature but some may find it even more amazing in the macro view. For example, bioluminescence is found across the animal kingdom, from jellyfish and worms to squids and sharks, from fireflies to glow worms, across the plants and algae, fungi and bacteria. It is thought to have evolved independently at least 27 different times in marine fish alone (Davis *et al.* 2016). In fact, in one deep-sea study collecting more than 350 000 video observations across 17 years, over 75% of the individuals observed were bioluminescent (Martini & Haddock 2017).

AURORA AUSTRALIS

> *"To trace the story of the aurora through history is to trace the development of man from a creature of ignorance and superstition, through his renaissance of art and learning, to an analytical disciple of science and technology. But fortunately, man's transformation is not complete: Nature has contrived to clothe all objects of our scientific investigation, from the microscopic to the cosmic, in an aura of beauty and surprise. The aurora is perhaps the most spectacular of nature's contrivances to preserve the soul of the scientist."* (Eather 1980, preface, p. ix)

The Sun is a tempestuous body, roiling with violent outbursts in the form of sunspots, coronal holes, solar flares and coronal mass ejections, or CMEs (Palca 2013, Fox 2022, NOAA 2022). Sunspots are dark blotches on the Sun's surface below the corona; the dark spots result from cool regions caused by strong magnetic forces. Coronal holes are the hot, glowing outer layer of the Sun's atmosphere which some believe are the skeletons of old sunspots. Solar flares are short periods of explosive energy released from the Sun, travelling at the speed of light and taking eight minutes to reach the Earth. CMEs are like giant bubbles of hot charged plasma shot into space, which take one to three days to reach the Earth. Coronal hole winds are typically gradual, whereas CME winds are more of a jolt. CMEs are often accompanied by solar flares, but they are not the same. Aurorae can result from both.

The Sun's energy is carried towards the Earth on a stream of electrically charged particles (mostly protons and electrons) known as the solar wind (NASA 2002). The Earth's magnetic field deflects these particles as they approach, creating a cavity in the solar wind (the magnetosphere) and a large tail on the night side of the Earth, that is, away from the Sun. Energy leaks into the magnetosphere, and the aurora results from electrons in

the tail becoming unstable and losing energy. Most of our knowledge about the aurora comes from the northern hemisphere, but because it is a planetary phenomenon, we can assume that these principles hold true in the south.

Seasonality

One of the earliest scientific patterns to be recorded was the correlation between the aurora and the spring and autumn equinoxes, that is, that the aurora occurs most frequently around March–April and September–October annually (Young *et al.* 2022). The explanation for this semi-annual variation is in the orientation of the Sun's magnetic field (known as the *Bz component* and carried to Earth on the solar wind) relative to ours. When the solar wind's "north-south" component is more or less opposite the "north-south" component of the Earth's own magnetic field, this opens a hole thus allowing the solar wind to flow more easily towards Earth's magnetic poles. This is known as the *Russell-McPherron Effect* (Russell & McPherron 1973, Young *et al.* 2022).

It is also commonly believed that winter is "aurora season", stemming from the fact that there are more night-time hours during the winter, hence more hours in which the aurora may be seen. From the small collection of records listed below, as well as photographic records on social media, and this author's own experience, it is clearly possible to see the aurora during any season of the year.

Time of day

The aurora may be visible from early dusk to late dawn; however, it tends to be most intense and dynamic around solar midnight, or the point in the night where the Sun is equidistant between the dusk and dawn. This is due to the physics of the electrons leaking from the tail of the solar wind into the magnetosphere (the cavity in the solar wind on the night side), and from there into our atmosphere (NASA 2002). Moreover, according to the website AuroraBorealisObservatory.com, if you are located before solar midnight, the aurora expansion will most likely come from the east, but when you have passed solar midnight, the expansion will typically seem to come from the west. This is useful if you are looking for a location to take pictures of the expansion phase of substorms. Before midnight, choose a location that has your desired composition towards the east, and after midnight, towards the west (Hanssen 2021).

Interannual variation

Over time, the Sun's activity builds to a maximum, its magnetic field reverses, then activity settles back down to a minimum, and another cycle begins. This cycle, known as the Solar Cycle, occurs approximately every 11 years (NASA 2020). During a solar maximum, the Sun produces around three CMEs per day, whilst activity drops to one every five days or so near a solar minimum (Fox 2022). Our next solar maximum is expected to occur in July 2025 (NOAA 2020), so aurora activity is anticipated to increase up to then.

Colours

An aurora results from charged particles spewed out from the Sun and hurtled across space and its colours are determined by the interaction of several factors: the type of gas, the altitude and the solar particles (Aurora Live 2020, Lummerzheim 2021). Different atoms and molecules in the upper atmosphere interact with charged particles to produce characteristic wavelengths (colour) via fluorescence. Even though the most abundant gas in our atmosphere is molecular nitrogen, we most commonly associate the colours of oxygen with the aurora. At mid-altitudes (100–250 km), monoatomic oxygen (O) typically emits photons with a lemon-green glow, but together with blue N_2+ appears as more of a lime green colour. In a super-excited state at higher altitudes (beyond 250 km), oxygen may emit a red-orange glow. Diatomic nitrogen (N_2) emits deep red photons, while its ionised form (N_2+) emits a deep blue-purple glow. In the lower atmosphere (80–100 km above the earth), a pink glow results from a combination of red N_2 and blue N_2+.

The aurora may be visible as any of numerous different structures, including:

- a glow above the horizon, which may be green or reddish or both
- beams that shoot up into the sky and travel across the horizon
- giant blue rays of diffuse light (these are not yet well understood)
- arcs of light
- undulating curtains (uncommon in Tasmania)
- Strong Thermal Emission Velocity Enhancement (STEVE), an aurora-like beam of purple and green light, resulting from a ribbon of hot gases in the atmosphere.

The more vibrant the aurora, the more extreme the geomagnetic risk to the electricity grid and magnetic media. For example, a solar superstorm known as the Carrington Event in August/September 1859 produced a spectacular aurora but also wreaked havoc on telegraph systems around the world (Wikipedia 2022). So strong was the geomagnetically induced current that the telegraph between Boston and Maine was run with perfect communication for two hours on "celestial power", that is, without battery power (Boteler 2006, Green *et al.* 2006). In 2013, Lloyd's of London issued a report estimating the impact on America of a Carrington-level event at that time. Among their findings:

> *"The total U.S. population at risk of extended power outage from a Carrington-level storm is between 20–40 million, with durations of 16 days to 1–2 years. The duration of outages will depend largely on the availability of spare replacement transformers. If new transformers need to be ordered, the lead-time is likely to be a minimum of five months. The total economic cost for such a scenario is estimated at $0.6–2.6 trillion USD."* (Lloyd's 2013)

That estimate was a decade ago.

Plate 1 — Aurora Australis in Tasmania. **A** at Tessellated Pavement, copyright Fiona Gumboots Walsh; **B** at Gordon, copyright Luis Mora; **C** at Howden, copyright Lisa Gershwin; **D** with bioluminescence at Ralphs Bay, copyright Fiona Gumboots Walsh.

Using historical records dating back more than 2000 years, Lloyd's estimated the periodicity of a Carrington-level event of around 150 years, with a reasonable range of 100–250 years. The Carrington Event occurred 163 years ago. How a Carrington-level event would impact Tasmania is unknown, but we can reasonably expect it to be highly disruptive.

To reflect on Eather's (1980) evocative quote, it seems that the aurora may be nature's most glorious manifestation of both beauty and beast. Beauty, in the mesmerising lights that dance in the sky, and beast, in that the more vivid these lights are to our unaided eye, the greater the geomagnetic threat to humanity.

Early reports of the aurora in Tasmania

The Aurora Australis, or Southern Lights, is a common phenomenon in Tasmania's night skies (pl. 1) and has been recorded since the earliest times. In 1851:

> *"Mr. Milligan stated that he observed the Aurora of the 4th* [of September] *from 9 to 10 o'clock p.m., (when it began to wane), at Oyster Cove, in D'Entrecasteaux Channel; that in Hobart Town, the following evening, about half-past 9 o'clock, he observed a few faint auroral coruscations in the south; and that the aborigines reported the occurrence from 8 to 9 on the same evening of an Aurora of unusual brilliancy, displaying long shoots of red, blue, and green light, accompanied at intervals with a crackling noise, which they exemplified by snapping the fingers repeatedly."* (Milligan 1851, p. 161)

Other descriptions of the aurora in Tasmania include:

On 21 April 1858 the *The Sydney Morning Herald* reported:

> *"Aurora Australis. – This meteorological appearance, which is rather unusual in Tasmania, was visible on Friday night* [16 April], *commencing shortly before ten o'clock. The Aurora was not very luminous, but sufficiently so to constitute a beautiful spectacle, the night being very clear and brightly star-light."* (Anonymous 1858, p. 8)

On 2 September 1859, simultaneously observed in Tasmania, Victoria, San Francisco, and across Europe, *The Argus* reported:

> *"AURORA AUSTRALIS AND BOREALIS. … calls your attention to the above phenomenon making its appearance here simultaneously with its appearance in Tasmania… This splendid phenomenon occurred with increased brilliancy last night. About half-past 3 in the afternoon the declination instrument at the Observatory, on the Flagstaff-hill, commenced to be disturbed very suddenly, and the intensity of all the phenomena from that time increased rapidly. Professor Neumayer at once predicted a magnetic storm, and soon after sunset an aurora was displayed such as has seldom been witnessed in the southern hemisphere."* (Anonymous 1859a, p. 6)

It is notable that the above aurora was the Carrington Event, the extreme solar storm discussed earlier. This CME was so powerful that it was believed to take only 17.6 hours to reach the Earth (compared to the more typical three days), and it was visible around the world, including lower latitude areas like Queensland, Hawaii, Cuba, and even Colombia, close to the equator. In the Rocky Mountains, it was so bright that it fooled miners into thinking it was morning, and in northeastern United States people could read a newspaper by its light (Wikipedia 2022).

On 13 December 1859 *The Sydney Morning Herald* reported for Hobart:

> *"THE AURORA AUSTRALIS. – …appeared in great magnificence on Tuesday night at Hobart Town. It reached from the western to the southern and south-eastern horizons. At about ten o'clock, and from that to half-past ten, it was most brilliant. …The light swept upwards to the meridian in long streamers, much like the tail of a comet, and across these there fluttered brilliant corruscations rolling upwards like the waves on the shore. But the most splendid effect was seen at about a quarter-past ten, when from behind the south-western end of Mount Wellington a beautiful stream of rose-coloured light shot upwards to the meridian, gradually collapsing into a narrow strip, very brilliant, and of the colour of carmine. … We have never seen a more splendid Aurora than this."* (Anonymous 1859b, p. 3)

On 9 August 1917 in Hobart, Launceston and Zeehan, reported in *The Mercury*:

> *"AURORA AUSTRALIS. OBSERVED IN TASMANIA. A FINE SPECTACLE. An exceptionally fine display of the natural phenomena known as the Aurora Australis or 'Southern Lights' was seen in various parts of Tasmania last evening. In Hobart it became visible at about 6.30 p.m., when the whole of the southern sky became a brilliant pink. At first the glare seemed as though it were caused by a huge bush fire, but it gradually spread until it extended over nearly half the sky with rays of light shooting out in all directions and constantly appearing and disappearing. … OBSERVED AT LAUNCESTON. … The illumination covered about half the sky, stretching from the zenith to the horizon from a little north of west to just south of east. On the western edge there was a shaft of bright light resembling a huge searchlight, widest at the horizon and terminating in several shifting points well up the dome. …The display lasted for more than a quarter of an hour and was watched by a large number of citizens. … THE SIGHT ON THE WEST COAST. ZEEHAN. Shortly after 7 to-night a magnificent view of the Aurora Australis could be*

Plate 2 — Bioluminescence in Tasmanian Sea Sparkles *Noctiluca scintillans*. **A** daytime surface slicks at Bellerive Yacht Club; **B** nighttime bioluminescence at Marieville Esplanade. Both copyright Lisa Gershwin.

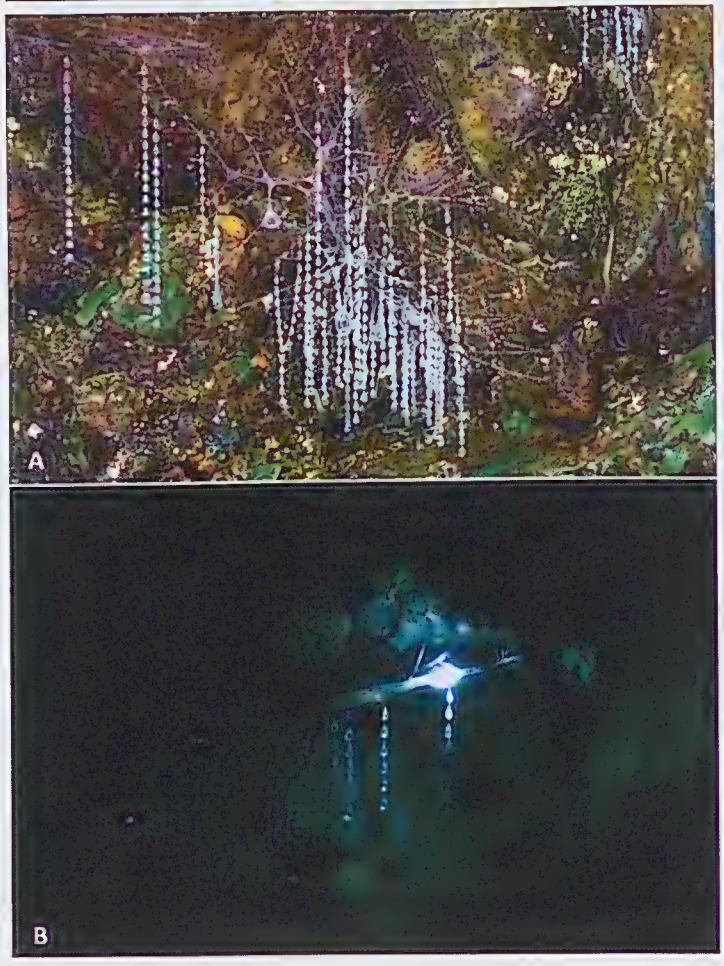

Plate 3 — Bioluminescence in Tasmanian Glow-worms *Arachnocampa tasmaniensis*. **A** in daylight, copyright Daniel Dirks; **B** bioluminescence, Jon Sullivan CC iNaturalist.

> *obtained, and the spectacle was visible for nearly an hour. It was crimson and illuminated the southern clear starlit sky from the horizon to the zenith. Luminous arches frequently changed their shape, forming boreal crowns, and rays of changing tints rose perpendicularly, and appeared and disappeared, and moved slowly eastward. … It was the finest sight witnessed on the West Coast in the memory of the oldest inhabitants."* (Anonymous 1917a, p. 4)

This same event was also observed in Wynyard, reported in *The North Western Advocate and the Emu Bay Times*:

> *"AURORA AUSTRALIS. Several beautiful views of the Aurora Australis were visible in Wynyard on Thursday evening, and many people left their tea to gaze heavenwards at this picturesque phenomenon, with its varied hues. …"* (Anonymous 1917b, p. 3)

Of course, many other aurorae have been observed in Tasmania since.

Finding the Aurora Australis in Tasmania

The Aurora Australis is fairly common in Tasmania and may be viewed throughout the state, most often by looking south.

Understanding Alerts. It is now possible to receive alerts of impending or current auroral activity. Numerous aurora apps and government space weather sites issue alerts, and most include information on six values and indices that are helpful in understanding the likelihood of an aurora. These are summarised below, with more thorough explanations on the websites Solar Ham (https://www.solarham.net/) and Dark Sky Finder (https://darksitefinder.com/reading-aurora-charts/).

KP Index: A measure of geomagnetic activity in the Earth's atmosphere, expressed in three-hour increments, and the corresponding width of the auroral oval, or the latitudes where the aurora will be visible. KP comes from "Planetarishe Kennziffer", German for "planetary index". A higher KP index means the aurora will be visible at lower latitudes. For example, in general terms, a KP 3 may be seen on camera in southern Tasmania, a KP 4 is likely to be seen on camera throughout Tasmania and may be seen faintly with the naked eye, a KP 5 may reveal more structure with the naked eye and brilliantly on camera and, anything higher is likely to be spectacular in Tasmania.

G Index: A measure of the strength of a geomagnetic storm. KP 5 through 9 are elevated to a storm classification scale, where KP 5 is considered a G1 storm, KP 6 corresponds to a G2 storm, and so on.

Solar Wind Speed: The speed of the charged particles streaming from the Sun. Its baseline is normally around 300 km/sec. Typical windspeed during an aurora will be in the 500–600 range but may exceptionally reach more than 1000 km/sec. In general, the higher the windspeed, the more vivid and dynamic the display.

Bz: A measure of polarity of the Sun's magnetic field carried through the solar system by the solar wind (the Interplanetary Magnetic Field, or IMF). The Earth's magnetic field points north. When the Sun's magnetic field (IMF) points sharply south, it may cancel the Earth's magnetic field, creating an opening for the solar wind to reach our atmosphere. Thus, the more strongly the Bz component is trending south, the more likely it is for a stronger aurora to form.

Bt: A measure of the strength of the IMF, with higher strengths being more favourable.

Density: A measure of the energetic particles of the solar wind (per cm^3); in general, a density of 10 or higher is favourable.

SEA SPARKLE

> *"The sea was luminous in specks & in the wake of the vessel, of a uniform, slightly milky colour. – When the water was put into a bottle, it gave out sparks for some minutes after having been drawn up. – When examined both at night and next morning, it was found full of numerous small (but many bits visible to the naked eye) irregular pieces of (a gelatinous?) matter. The sea next morning was in the same place equally impure."* (Charles Darwin, Beagle Zoology Notebook, first two handwritten entries in Campbell 2012, p. 449)

Marine bioluminescence is found all over the world, from the Arctic to the Antarctic, from beaches to the open ocean and deep sea. It is so common, that several places have formed tourism industries around their bioluminescence: Luminous Lagoon in Jamaica, Halong Bay in Vietnam, Bioluminescent Bay at Grand Cayman, and Bahía Bioluminiscente (aka Mosquito Bay), Laguna Grande and La Parguera in Puerto Rico.

Marine bioluminescence in Tasmania

Many marine species are capable of bioluminescence. "Sea Sparkle" in the Tasmanian context generally refers to the invasive dinoflagellate *Noctiluca scintillans*. Blooms of *Noctiluca* follow a predictable pattern: they begin with a small estuarine seed population, feast on diatom blooms responding to upwelling or other nutrient input, surface and starve in calm water, then form red surface slicks as they die (Hallegraeff *et al.* 2020). Bioluminescence is associated with this last stage, that is, their die off (pl. 2).

Whereas the aurora is both beauty and beast in outer space, so too, is the Sea Sparkle in inner space. Beauty, in the incredible displays of bioluminescence that it gives off en-masse, and beast, in its triple impact of toxicity, low oxygen and plankton consumption (Hallegraeff *et al.* 2019). *Noctiluca* is an invasive pest that competes with and consumes other species higher in the food chain (Quevedo *et al.* 1999, Umani *et al.* 2004). India provides a cautionary tale, where hypoxia-enhanced *Noctiluca* blooms feed on diatoms, they in turn are fed on by jellyfish blooms, which also consume zooplankton (do Rosário Gomes *et al.* 2014, Thomas *et al.* 2020) and hence the greater *Noctiluca*'s

intensity and duration, the greater its threat to the local fisheries and ecosystems.

History of Sea Sparkle in Tasmania

Along Australian shores, the species most likely to be observed luminescing is the cosmopolitan red tide forming heterotrophic dinoflagellate *Noctiluca scintillans* (Latin for "sparkling nightlight"). *Noctiluca* was first reported in Australia in 1860 from Sydney Harbour (Bennett 1860). Reports from the 1930s and 1950s considered it to be just a minor part of the plankton, and confined to east coast estuaries, respectively (Hallegraeff *et al.* 2008). It wasn't until 1982, some 120 years after the species was first observed, that its first Australian "red tide" event was reported, this time in Lake Macquarie hundreds of kilometres to the north of its original record (Ajani *et al.* 2001). By the 1980s, it had reached north Queensland; by 2008, Western Australia and South Australia; and by 2014, the Northern Territory (Hallegraeff *et al.* 2020). Today, *Noctiluca* frequently forms spectacular blooms up and down the New South Wales coastline, especially around Jervis Bay (FB Group 2022).

In Tasmanian waters, *Noctiluca* was first observed in March 1994 and has been growing its distribution since (Hallegraeff *et al.* 2008). Driven by climate warming, it is expanding southward by around 40 km per year; and by 2010, it had penetrated the Southern Ocean (McLeod *et al.* 2012). Tasmanian research has determined that *Noctiluca* can reproduce at 10°C and survive at 7°C but is unable to thrive at 25°C (Hallegraeff *et al.* 2019). Research in Germany found that *Noctiluca* can survive below 0°C (Elbrachter & Qi 1998) meaning that Tasmanian water is well within *Noctiluca's* preferred parameters: for example, the sea surface temperature at Hobart ranges between a high of 18.1 and a low of 11.9°C (https://www.seatemperature.org/australia-pacific/australia/hobart.htm).

Under normal circumstances, that is, in relatively low numbers, *Noctiluca* is generally not overly dangerous (Hallegraeff *et al.* 2020). However, surface slicks with concentrations of 1–2 million cells per litre can be hazardous to aquaculture and fisheries due to high ammonia and reduced oxygen (Hallegraeff *et al.* 2019). For example, a seven-month-long bloom event off Tasmania's east coast in 2001–2002 posed a significant threat to the aquaculture industry, particularly salmon (Hallegraeff *et al.* 2008). Anecdotal evidence exists of shellfish tasting like ammonia when associated with *Noctiluca* slicks (Hallegraeff *et al.* 2020). Moreover, field and laboratory observations on *Noctiluca* grazing demonstrate that it consumes toxic dinoflagellates; its harmful effects may therefore be magnified when the phytoplankton community becomes dominated by dinoflagellate assemblages (Escalera *et al.* 2007).

Large blooms of *Noctiluca* occur occasionally in Tasmania. The previously mentioned one, for example, lasted from September 2001 off the east coast to March 2002 off Nubeena (Hallegraeff *et al.* 2008). Another of this species' spectacular blooms here was first reported in May 2015 in Ralphs Bay on South Arm (Gershwin *et al.* 2015). Primarily confined up to this point to scholarly appreciation, the 2015 bloom "went viral". The bloom was first found by aurora chasers, who initially became frustrated with the blue lights in the water interfering with their aurora photos, until they realised the source. This bloom caused a media sensation, and within days, thousands of people were flocking to this remote beach on cold autumn nights to observe this incredible natural phenomenon (Salmon 2015).

GLOW-WORMS

While William Shakespeare (1599–1601) and William Wordsworth (1849) waxed poetic about glow-worms, species in Tasmania have very little in common with their European forms. European glow-worms are more widely known as Fireflies. Northern hemisphere glow-worms are larval and adult female beetles (Order Coleoptera), *Lampyris noctiluca* (Linnaeus, 1767), that glow a brilliant yellow-green. In contrast, the Australian and New Zealand glow-worms, are the cave-dwelling snare-forming larvae of fungus gnats (Order Diptera), *Arachnocampa* spp., that glow magnificently blue and demonstrate why common names are not always the most useful way of communicating about species.

While Shakespeare asserted that the glow-worm's light is "uneffectual", bioluminescence is in fact one of the most efficient types of light known: "Nearly all of the energy input into the reaction is transformed into light. The reaction is 85%–90% efficient. As a comparison, the incandescent light bulb only converts about 10% of its energy into light, and a 150 lumen per Watt LED converts 20% of input energy to visible light" (Singh *et al.* 2018, pp. 27–61).

Bioluminescence in dipterans is restricted to the fungus gnats (Mycetophilidae: Keroplatinae) (Sivinski 1998). The most well-known of these are in the genus *Arachnocampa*, meaning "spider web grub" in reference to their sticky snares. Eight are found in Australia and one in New Zealand (Baker 2010). Only one is identified in Tasmania, *Arachnocampa tasmaniensis* (Ferguson 1925). Varying degrees of the morphology and life cycle are well documented for three species: New Zealand's *A. luminosa*, Queensland's *A. flava* and *A. richardsae* from New South Wales (Gatenby 1959, 1960; Richards 1960, Harrison 1966, Stringer 1967, Baker & Merritt 2003, Meyer-Rochow 2007). The duration of growth phases differs from species to species. In general, the glow-worm spends around nine months in its bioluminescent larval stage, living in a hollow, tubular horizontal runway of silk and mucus, from which it suspends a chandelier-like snare of sticky threads for catching prey attracted by its posterior glow. Once they reach a mature size, 30–40 mm, larvae pupate, this stage lasting a few weeks. The adult gnat hatches and lives only a few days and does not feed; its sole focus is to find a mate. Eggs incubate for a few weeks, before hatching into the larval glow-worm stage. The biology of *A. tasmaniensis* is probably similar.

Bioluminescence is produced internally in their Malpighian tubules, branches from the gut that normally

function as insects' kidneys but are modified for light production (Chandler & Baker 2009). In the Fandango animated film, *Surf's Up*, a lava-boarding scene memorably portrayed two penguins falling into a pool of glow-worm poo (https://www.youtube.com/watch?v=YHirkSmJcEU). This led to online sources claiming that glow-worms don't defecate; instead, their solid and liquid metabolic wastes are used as fuel for producing light (Gardner 2009). It's an amusing proposition, but according to entomologist and glow-worm expert David Merritt of the University of Queensland, "There is no evidence that waste materials are used in producing the light" (Merritt 2022).

History of glow-worms in Tasmania

The first glow-worm described in Australia was in fact *A. tasmaniensis* from the Ida Bay Caves in Tasmania's far south (Ferguson 1925). Even before its original description, high profile accounts of glow-worms in Tasmania were published. Johnston discussed finding glow-worms at the caves at Ilfacombe (now Flowery Gully) near Beaconsfield in his *Systematic Account of the Geology of Tasmania* (Johnston & Etheridge 1888), and an anonymous author recounted in *Scientific American* discussion about glow-worms at Ida Bay during a meeting of the Royal Society of Tasmania (Anonymous 1891). The species is now known from many locations around the state (Goede 1967, Baker 2010).

Glow-worms are common in caves and cave-like habitats, that is, dark, still habitats with very high humidity (pl. 3). These include abandoned mines and railway tunnels, rainforests, leafy glades and grottos, damp overhangs like roadcuts and trail cuts, and even under verandas. Glow-worms are strongly associated with permanent streams, either cave streams or surface streams (Goede 1967). Plowman *et al.* (2013) outlined the history and ecology of glow-worms in Australia and New Zealand and provided local information on Tasmanian sites and species.

Research on the circadian rhythms of Tasmanian glow-worms has revealed fascinating insights. Firstly, they may be seen at any time of day but typically glow most brightly in the late afternoon rather than at night (Merritt 2022). Secondly, the glow-worms within a single cave will synchronise their light-dark cycle with each other, but the populations in different caves have different cycles (Merritt & Clarke 2011, Maynard & Merritt 2013). At Ida Bay, for example, pupae and adults are strongly seasonal, commonest in spring and summer, with their increase in numbers tied to the increase in food capture in the larvae's snares (Driessen 2010). The larvae are present throughout the year, but their glow cycles differ. Mystery Creek Cave glow-worms glow most abundantly from late spring through to autumn, while those at Exit Cave have no consistent seasonal pattern (Driessen 2010). Multi-day timelapse digital photography at Mystery Creek has shown that larvae located outside the cave or at the cave mouth luminesce only at night, whereas those located deeper inside the cave glow most strongly in the afternoon (Merritt *et al.* 2012). Intriguingly, Tasmanian glow-worms can start glowing at any part of the day-night cycle, compared to Queensland's *A. flava*, which is locked into nocturnal luminescence (Merritt *et al.* 2012).

Glow-worm larvae are highly sensitive to lights other than their own. In general, glow-worms will stop glowing when exposed to 1–5 minutes of white light and require on average around 30 minutes to recommence glowing, reaching pre-disturbed glow intensity by around 70 minutes (Mills *et al.* 2016). Experiments with one-minute exposure to other colours of light suggest that there are no safe colours of light to use with glow-worms: their reaction to blue light was similar to white, while red or green lights caused somewhat less disturbance but ultraviolet (UV) caused more (Mills *et al.* 2016). To determine whether cave lighting associated with tourism ventures has a deleterious effect on the glow-worms' wellbeing, a study comparing bioluminescence in viewing chambers and "unvisited" chambers in Marakoopa Cave in Tasmania's north, concluded that in carefully controlled situations with a limited number of brief exposures, the glow-worms did not appear to be impacted by the lighting (Merritt & Clarke 2013).

Tasmania is well-suited to glow-worms, due to the prevalence of limestone formations, and thus caves. The middle to upper Ordovician Gordon Limestone is widespread through western Tasmania and accounts for over 90% of Tasmanian caves (Goede 1967). In his thesis, Stefan Eberhard studied more than 130 caves in 31 karst areas, representing around 14% of the known caves and half of Tasmania's cavernous karst areas (Eberhard 1992). However, some of these caves have been historically under threat. At Ida Bay, for example, a limestone quarry (Blayneys Quarry) operated near Mystery Creek Cave during the Second World War, and another limestone quarry, Benders Quarry, was closed in 1992 because of its deleterious impacts on the Exit Cave system (Eberhard 1995, Eberhard 1999).

The world's entomofauna are in conservation crisis. A recent review concluded that almost half the world's insect species are rapidly declining and a third are threatened with extinction (Sánchez-Bayo & Wyckhuys 2019). Glow-worms in England have declined 75% in less than 20 years (Gardiner & Didham 2020). Snare-forming glow-worms are highly sensitive to changes in their habitat. Natural threats include winter flooding, predation by other cave fauna and fungal disease, while human threats include touching of larvae or their snares, air quality issues like carbon dioxide from visitors' exhalations or smoke disturbance from fires, changes in water quality affecting food supply, or changes in cave microclimate including, importantly, desiccation (Merritt & Clarke 2013). It is imperative that management guidelines are in place for their reservation and protection, and authorities can limit visitations to glow-worm sites to protect these fragile species (Glow Worm Tunnel Management Committee 2020).

GHOST MUSHROOMS AND OTHER LUMINOUS FUNGI

Our fascination with bioluminescence in fungi dates back thousands of years (Harvey 1957, Lee 2008). In their paper, 'Early accounts of fungal bioluminescence', Dean Glawe and Winton Solberg take the reader on a journey through European science, from Boyle's proof in the mid-1600s that luminous wood requires air to produce light, to Bacon's observations later that century on the essential similarity of the luminescence of wood and other objects, to Heller's demonstration two centuries later that the light emanating from decayed wood is fungal in origin (Glawe & Solberg 1989). The reader is treated to American philosopher Cotton Mather's attempt to harmonise science with religion, using fungal bioluminescence to show that "even the most objectionable and troublesome characteristics of plants can be beneficial", as part of his argument to infer the existence of a purposeful Creator. We are then treated to understanding the context of Olaus Magnus's solution to the long nights of Scandinavian winters by using rotten bark to produce light (Glawe & Solberg 1989, pp. 296–299).

Gates and Ratkowsky's *A Field Guide to Tasmanian Fungi* details 650 species (Gates & Ratkowsky 2016), and estimate that a further 300–400 are known here (Genevieve Gates, pers. comm. August 2022). Of these thousand or so species, members of the Facebook groups *Tasmanian Fungi* and *Bioluminescence Tasmania* have found three species that luminesce, plus another species that may, outlined below, with more still awaiting discovery.

Fluorescence in fungi has been known for decades, and indeed, has been used as a reliable taxonomic character by numerous workers (e.g., Reinhold 2020 synopsis). Gill (1995) reported that the flesh of Australian *Dermocybe* was "intensely fluorescent when viewed in U.V. light". More recently, Reinhold (2020) detailed the fluorescence of 14 species of fluorescent fungi from just 12 nights exploring in and around Cairns. Other than these reports and social media postings by a few dedicated naturalists, it appears that fungi fluorescence has been all but ignored in Australia, and particularly in Tasmania.

Ghost Mushroom

Ghost Mushroom (*Omphalotus nidiformis* (Berk.) O.K. Mill. 1994) is by far the largest and commonest of the fungi known to luminesce in Tasmania (pl. 4a, 4b). It is a gilled basidiomycete primarily found in two disjointed populations in southern Australia, one in southwestern Western Australia and the other in much of eastern Australia. It is generally found in temperate forests, but more than 4000 records in the Atlas of Living Australia (ALA) indicate that its distribution ranges from Port Lincoln in South Australia to Mowbray Forest Reserve in Julatten, Far North Queensland, including throughout much of Tasmania, as well as a record from Lord Howe Island in June 2019 (ALA 2022). It has also been reported from Norfolk Island (Cooper 2011) and Kerala, India (Shirmila & Radhamany 2012). As its specific epithet suggests (*nidus* is Latin for nest), its fruiting bodies are nest-shaped, funnel-shaped, or fan-shaped. They grow to 30 cm diameter, though typically much smaller. Dead or dying stumps, trees and logs of eucalypts and pines are the most frequently reported hosts. The caps come in two colour morphs, most commonly cream-coloured with a golden or orange central depression, or smoky grey, purplish or black; the whitish or cream-coloured lamellae run the length of the stipe.

The first account of the species we now recognise as *Omphalotus nidiformis* was in an 1841 letter by the Scottish naturalist James Drummond to Sir William J. Hooker, published the following year in the latter's *London Journal of Botany* (Drummond 1842). Before any name had been given to the species, Drummond described a specimen around 25 cm across and weighing more than two kilograms; this was similar in form to some small specimens found 6–7 years earlier growing on the stump of a Banksia tree near a Perth jetty on the Swan River. Both were remarkable for their brilliant luminescence. Subsequently, the species was described by the English naturalist Miles Joseph Berkeley (1844) based on Drummond's observations.

The following year, similar material was collected by the Tasmanian botanist Ronald Campbell Gunn, and forwarded to Berkeley, who described it as a different species, *Agaricus (Pleurotus) phosphorus* (Berkeley 1848). In all, Berkeley named at least four different forms of large glowing mushrooms from southern Australia, which have since been synonymised, and after a lengthy period of nomenclatural instability, *O. nidiformis* was given its present classification by Orson K. Miller, where it has remained since the late twentieth-century (Miller 1994).

Ethnobotanist Philip A. Clarke of Adelaide discussed the Aboriginal connection to fungi, including *O. nidiformis*. "In Aboriginal Australia it was widely believed that certain species of fungi retained power from their connection with the heavens.... Falling stars appear to be associated with the idea of evil magic in many tribes" (Clarke 2015, pp. 23–37). Clarke explained that some tribes believe that mushrooms are fallen stars and look upon them as being endowed with evil magic. He then recounted the story of Drummond, who showed a glowing specimen of *O. nidiformis* to local Aboriginal people, whereupon they cried out 'Chinga!', their name for a spirit and seemed much afraid of it (Drummond 1842). Similarly, the Koombumerri people of the Springbrook Plateau in southeast Queensland believed that the glowing fungi were the spirits of their ancestors and that it was disrespectful to look at them (Maguire 2011).

The ecological driver for luminescence in *O. nidiformis* is under debate. It is generally assumed that *O. nidiformis* luminesces to attract prey as a means of spore dispersal, as in other species (Oliveira *et al.* 2015, Weinstein *et al.* 2016). Indeed, it is confirmed as a host for fungus beetles (Fearn 2017), and in situ, *O. nidiformis* typically appears nibbled with different sized chunks missing, along with beetles and millipedes often milling about. Weinstein and his colleagues, however, called the spore dispersal hypothesis into question based on its autumnal fruiting season in their region being out of sync with summertime

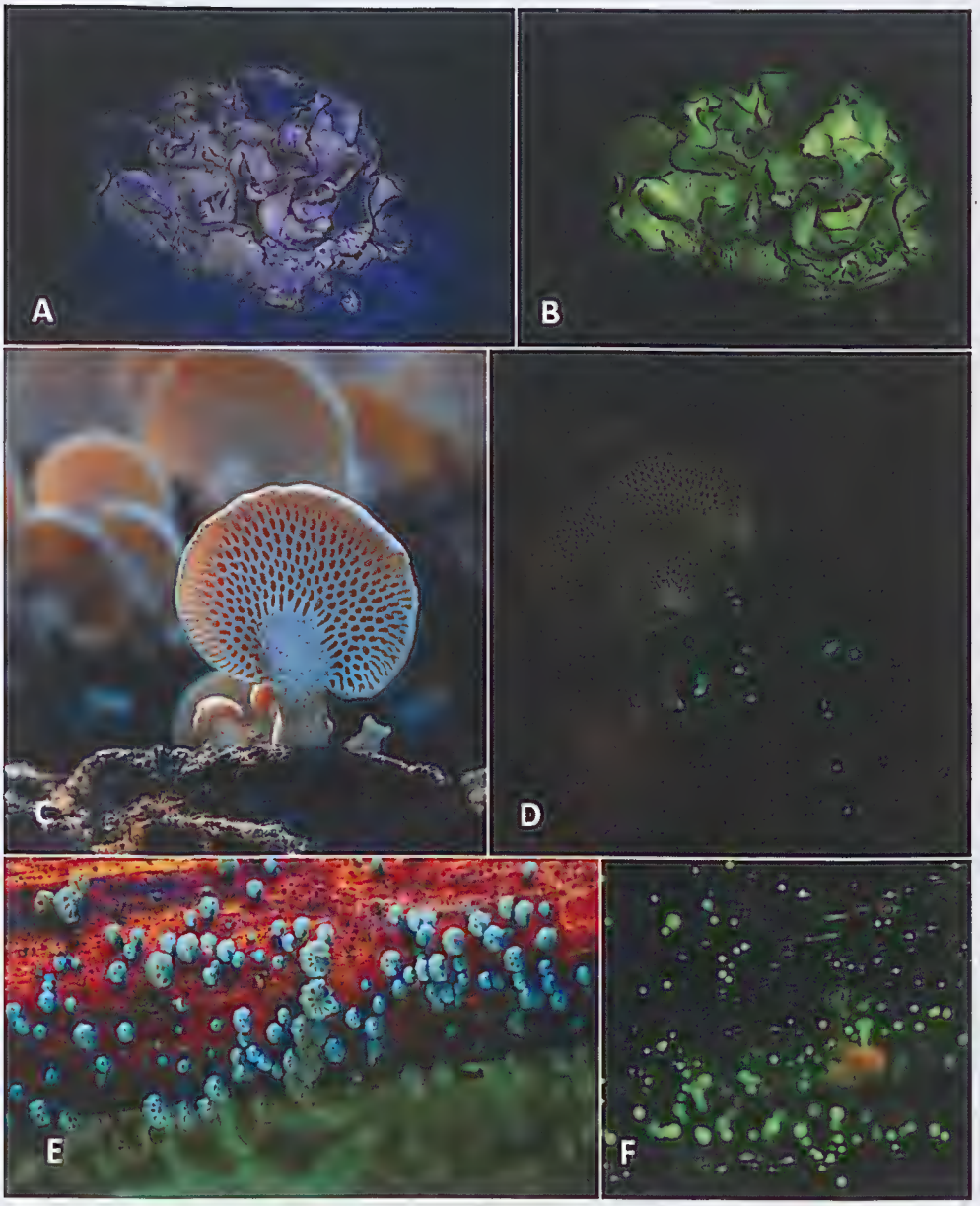

PLATE 4 — Bioluminescence in Tasmanian mushrooms. **A**, **B** Ghost fungus Omphalotus nidiformis, both copyright Lisa Gershwin; **C**, **D** Ping Pong Bats Panellus pusillus, both copyright Ryan Shan; **E**, **F** Tiny Blue Lights Mycena azulina, both copyright Bronek Burza. A, C and E white light, B, D and F natural bioluminescence.

peak insect periods, its use of constant luminosity rather than a diurnal rhythm, and their experimental results with flying insect attraction (Weinstein *et al.* 2016). But they conducted their experiment in the wintertime when one might expect less insect activity. Moreover, their experimental design seems open to question as they attached a cut piece of glowing fungus above one corner of a double-sided sticky trap which seems incongruous with methods of other studies. For example, Sivinski (1981) placed his glowing samples as close as possible to their original position, with the controls 80 mm to the side. By this standard, much of Weinstein's trap was a control. Another example is that of Oliveira and his colleagues (Oliveira *et al.* 2015), who covered their model fungi with scentless glue and measured the insects that landed on the glowing object itself rather than underneath it. The extent to which Weinstein's results would be repeatable in other conditions is unclear. For example, would their seasonality assumptions still hold true in areas like Tasmania, where *O. nidiformis* may occur any time of year, especially in the warmer months? Or, for example, might their cut pieces of fungus have exuded a chemical repellent of some sort, or might there have been an effect of hanging their sticky trap and fungus above the ground that was not accounted for?

A high level of community interest in these fascinating fungi has even led to a tourism industry built around *Ghost Mushroom Lane* in South Australia. This family-friendly site is within a commercial pine forest operated by Forestry SA, comprising a series of seasonal walking trails with evocative names like Fungi Hunter Alley and Neon Forest. Intense interest in Tasmanian *O. nidiformis* by photographers and

citizen scientists has led to a wealth of reports especially via the Facebook site *Bioluminescence Tasmania*, broadening our understanding of its seasonality. It has now been reported fruiting in every month in Tasmania, particularly from October through June.

Little Ping Pong Bats

As its common name suggests, this species *Panellus pusillus* (Pers. ex Lév.) Burds. & O.K. Mill. (a.k.a. *Dictyopanus pusillus* (Pers. ex Lév. Singer) resembles a tiny ping pong bat (pl. 4c, 4d). The fruit is flat and broadly round, with an array of tiny pores occupying the underside. It is typically found in large groups on stumps or wet wood. This species has more than 20 observations on the ALA, from across Tasmania dating from March 2001, though its luminescence has been known for more than half a century (Corner 1954, Wassink 1979). There is some discussion as to the real identity of Australian *Panellus cf pusillus*. Chew *et al.* (2015) discussed earlier authors' concerns about morphological anomalies in old world *P. pusillus*. Their own morphological and molecular analyses led them to distinguish their Malaysian specimens from Florida and Louisiana material, describing their form as *P. luxfilamentus*. Without explaining their reasoning, they stated, "*Panellus luxfilamentus* has been commonly misidentified as *Panellus pusillus* in Asia, Australia and New Zealand" (p. 185). Whether the Tasmanian form is the same as those found on the mainland, and conspecific with the Malaysian form, is unclear.

Tiny Blue Lights

The species *Mycena lazulina* Har. Takah., Taneyama, Terashima & Oba (2016) was only recently described in 2016 from Japan (Takahashi *et al.* 2016). It grows gregariously, with each fruit resembling a tiny dog's paw print, or wagon wheel. The stem is blue and its bioluminescence is green (pl. 4e, 4f). The first Tasmanian report was made on the Facebook site *Tasmanian Fungi* on 14 May 2021 (https://www.facebook.com/groups/tasfungi/permalink/2507723592707103/), discovered growing on a dead fallen rachis of the fern *Dicksonia antarctica* in the northwest.

Bitter Oyster

The species of fungi *Panellus stipticus* (Bull.) P. Karst, is known to be bioluminescent elsewhere but although the ALA lists over 100 observations of this species in Tasmania, it is yet to be confirmed to luminesce here (Gates & Ratkowsky 2016). According to ALA and other search sites, luminescence is well-known in eastern North American strains but not in those from elsewhere. Where it does luminesce, light is produced along the edges of the gills and where they join the stem and cap.

Biogeographical analysis using the ribosomal ITS region suggests that the species comprises two major clades, one from the northern hemisphere and the other from Oceania, with the New South Wales population basal to Tasmania and New Zealand (Jin *et al.* 2001). The Tasmanian population has 29 deleted base pairs compared to the northern hemisphere collections; whether this will ultimately result in a non-bioluminescent form, or an entirely different form, is yet unknown.

FLUORESCENT SCORPIONS

Fluorescence in scorpions under ultraviolet (UV) light was first reported about 70 years ago in Italy (Pavan 1954). That same year, another study on 18 species of arthropods across five classes and 13 orders, including scorpions, showed that 15 species fluoresced, ranging from mildly to brightly (Lawrence 1954). It is now thought that most scorpions fluoresce (Yoshimoto *et al.* 2020), enabling its wide use as a collection tool (Stahnke 1972) and as an aid to visualising their surface structure (Volschenk 2005). Scorpions are so strongly fluorescent, they continue to fluoresce when preserved in alcohol and even make the alcohol glow (Lawrence 1954, Rubin *et al.* 2017). Fluorescence in amber-fossilised scorpions has been widely reported in popular webpages (Kids Discover 2015), but the only reference to this is probably based on the findings of Rubin *et al.* (2017), who concluded that fossilised scorpions possessed the hyaline layer of the cuticle, a feature that appears to be associated with cuticular UV fluorescence. As is often the case with biofluorescence, compounds in the cuticle (or the shell, skin, or hair) are stimulated by UV light. Specific molecules absorb electromagnetic radiation (light) at shorter wavelengths that we can't see and re-emit it at longer wavelengths that are then visible. In the case of scorpions, the dominant compound is β-carboline, a tryptophan derivative, which produces an intense aqua colour when stimulated (Stachel *et al.* 1999).

Numerous hypotheses have been proposed as to *why they glow*, including acting as sunscreen, luring prey, finding mates or protection from parasitic infections (Lourenco & Cloudsley-Thompson 1996, Gálvez *et al.* 2020, Yoshimoto *et al.* 2020). However, the current widely accepted theory, from researchers in California is that fluorescence of the scorpions' own bodies enables them to detect UV light (such as on moon-lit nights), allowing them to make decisions about their activity levels (Kloock *et al.* 2010). Researchers from Oklahoma followed up with behavioural experiments on scorpions with blocked eyes under different light regimes and concluded that scorpions use their whole body as a photon-collector, transducing the UV light to the eerie colour, before relaying this signal to the brain, where decisions are made about detecting shelter (Gaffin *et al.* 2012).

History of fluorescent scorpions in Tasmania

Only one species of scorpion is known to occur in Tasmania, the Forest Scorpion or Wood Scorpion, *Cercophonius squama* (Gervais 1844) (pl. 5a, 5b). The species was first described from Van Diemen's Land as *Scorpio* (*Telogonus*) *squama*, before being moved to its present classification by Peters (1861). *Cercophonius squama* grows to 25–45 mm in length and is typically found in leaf litter or under logs. Like most other

species of scorpion, it is viviparous (Miller 2002). It is found throughout southern Australia in a disjunct population, with one population in southern Western Australia, and the other population in eastern Australia from the Eyre Peninsula in South Australia to north of Cairns in Queensland, including Tasmania (Carter & Murray 2020). To my knowledge, fluorescence in *C. squama* has not yet been studied.

FLUORESCENT MARSUPIALS, PLACENTALS, AND MONOTREMES

Eight years after Wood's lamp (the UV torch) was invented, the ethnologist and professor of medicine Hans Stübel (1911) studied rabbits, the edible frog *Rana esculenta*, a range of human tissues and numerous organic compounds from albumen to urine, concluding that "all animal cells and tissues have the property of fluorescing in ultraviolet light. … Only the presence of pigment or of hemoglobin and hemoglobin derivatives can impair or cancel this phenomenon. … Like the animal tissues, most of the organic compounds which compose them show a more-or-less strong fluorescence" (translation by Linda Reinhold, used with permission). Fluorescence was discovered in New World opossums in the 1970s and well characterised in the 1980s, with three-fourths of the species collectively displaying a psychedelic range of colours, including maroon, cinnamon (red orange), yellow, peach, pink, lavender, purple and blue (Pine & Abravaya 1978, Meisner 1983, Pine *et al.* 1985). However, this phenomenon in marsupials had already been described long before in Brushtail Possums *Trichosurus vulpecula* by Bolliger (1944), with one of the fluorophores even identified (Nicholls & Rienits 1971). (Fluorophores are fluorescent molecules that absorb light at a given wavelength and re-emit light at a higher wavelength, producing fluorescence in various colours.)

On 16 October 2020, a discovery published in the journal *Mammalia* was of Platypus *Ornithorhynchus anatinus* biofluorescing under UV light (Anich *et al.* 2021). The story propagated through the public's imagination as it swept the world's media and in rapid succession, fluorescence was confirmed in a range of marsupials and other mammals: Wombat sp. *Vombatidae*, Bilby sp. *Macrotis*, and Echidna *Tachyglossus aculeatus* (Edwards 2020), then the Tasmanian Devil *Sarcophilus harrisii*, bandicoot and bat species (Readfearn 2020). In fact, a zoologist in North Queensland had already been researching this very same question and had published on it prior to and independent of the Platypus discovery (Reinhold 2020).

In August 2022, it was announced with much public interest that the Thylacine *Thylacinus cynocephalus* was also fluorescent (Kean & Cutting 2022) and was the lead story on ABC news on the day of its announcement. While this finding is certainly exciting – given the prevalence of fluorescence in the marsupials it was to be expected. However, this discovery was made with the use of a microscope. Toussaint *et al.* (2022) found that when examined spectroscopically, all mammal fur emitted a blue photoluminescence, which, given its ubiquity, could be due to the amino acid residues in keratin or to intrinsic deep blue autofluorescence (Millington 2020). Autofluorescence is a process whereby biological and non-biological structures may naturally emit light. Pine *et al.* (1985) had noticed a similar phenomenon when fur was examined microscopically, even if no fluorescence was visible at the whole-pelt scale. My examination of a museum Thylacine mount with a dim 395 nm UVA light suggested pale blue fluorescence, especially on the neck, leg and ear. In life, the neck and ear displayed patchiness of paler highlighting, and the leg displayed pale blue compared to a distinctly purplish light beam shining on the table under the specimen; these colour differences were also apparent on my iPhone 13 Pro. On my computer screen, however, the neck and ear patchiness were largely smoothed out and the purplish beam on the table looked only marginally darker blue than the leg, highlighting a serious limitation with researching and documenting subtle colour differences. Whether these differences would be more apparent with another wavelength, or in the dark, or with a stronger light, etc., remains unknown, and we may never know whether a Thylacine would have fluoresced in life, in a way comparable to the psychedelic colours of its relatives, visible to the unaided eye under UV torchlight. As most tissues and organic substances fluoresce, autofluorescence is an obvious complication in fluorescence microscopy. However, outside the laboratory, this phenomenon is not yet widely known.

Given the prevalence of fluorescence in marsupials and other mammals, the obvious question is why. Conceivably, standing out to predators or prey could have its limitations to such an extent that one could easily imagine that natural selection would eliminate it rather quickly. Kohler and her colleagues (2019) observed that vivid pelage fluorescence is ubiquitous in the placental New World Flying Squirrels in the genus *Glaucomys*, leading them to propose four hypotheses as to why. Firstly, fluorescence is an adaptation to their nocturnal–crepuscular environment. *Glaucomys* squirrels are active at twilight and night and do fluoresce (108/109 museum specimens in three species), whereas 26 specimens of three species of diurnal sciurids did not fluoresce, strongly suggesting a functional adaptation to low-light environments rich in UV wavelengths. Secondly, fluorescence is important in snow-covered landscapes, given that snow cover reflects UV, amplifying its importance. Thirdly, fluorescence is used in intraspecific communication, specifically in its ventral prominence allowing *Glaucomys* to signal to one another as they glide among trees. And fourthly, fluorescence is useful in antipredator behaviour, either as a form of Batesian mimicry with co-occurring fluorescent owls or as camouflage in the squirrels' UV-saturated, fluorescing lichen-covered environment.

In Tasmanian marsupials, ventral fluorescence is particularly pronounced in bandicoots, which are entirely ground dwelling, so none of the above explanations seem to apply. As this same conundrum was noted by Reinhold (2020) for Queensland bandicoots, without resolution, more research is needed to help reveal the reasons why.

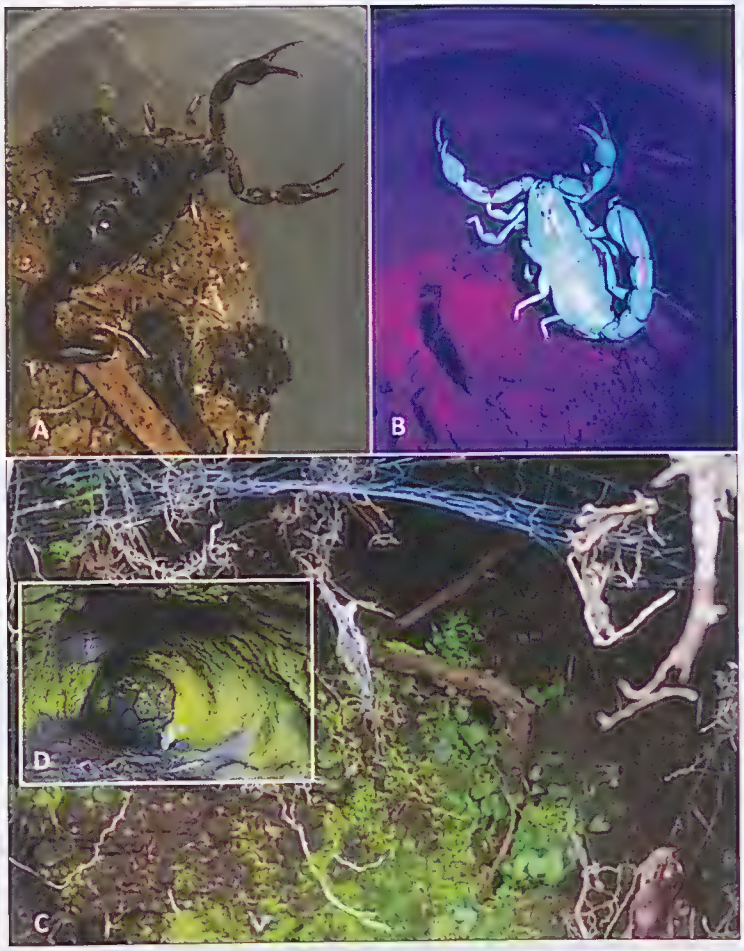

Plate 5 — Luminescence in Tasmanian scorpions and moss. **A**, **B** Fluorescent Forest Scorpion *Cercophonius squama*, left in indoor light, right, fluorescence under UV light, both copyright Lisa Gershwin; **C**, **D** Luminescent Goblin's Gold Moss *Mittenia plumula*. C, from Loongana, Tasmania, copyright Brenda Marshall. D (inset), for comparison, in a wombat burrow, New South Wales, copyright Tony Markham.

Plate 6 — Fluorescence in Tasmanian marsupials. **A** Tasmanian Devil *Sarcophilus harrisii*; **B** Eastern Quoll *Dasyurus viverrinus*; **C** Spotted-tail Quoll *Dasyurus maculatus*. Note ears fluorescing dark blue under UV light. All copyright Lisa Gershwin.

History of fluorescent marsupials, placentals and monotremes in Tasmania

Other than the previously mentioned accounts of the Tasmanian Devil and species coincidentally found in Tasmania, my own investigation on whole-animal fluorescence in roadkill and museum specimens has yielded some cautiously optimistic results. A summary of these observations, coupled with previous media reports, is presented in table 1.

The dark blue ears of the Tasmanian Devil (pl. 6a) are of a strikingly similar colour to that found by the Toledo Zoo in their live animal (Readfearn 2020), and both species of Quolls *Dasyurus* had a similar dark blue ear colouration (pl. 6b, 6c) to the devil, which differed markedly from other species' light blue ears. Moreover, the light blue ears of the Eastern Barred Bandicoot *Perameles gunnii* were similar in both museum and roadkill specimens (pl. 7a–f), and to those of other museum specimens including roadkill Pademelon *Thylogale billardierii*. Despite these similarities, it cannot be discounted that the museum fluorescence was due to an artifact of the preservation process, or something inherent to the skin. Notably, Bolliger (1944) found that the skin of the Brushtail Possum was coated with a substance that fluoresced sky blue and easily flaked off. Whether this may explain the light blue ears of so many of the museum specimens is unknown.

It is intriguing that the only species tested by the author so far that did not fluoresce was the Platypus *Ornithorhynchus anatinus*, across numerous museum specimens, whereas Anich *et al.* (2021) found that their American museum specimens (originally from Tasmania) fluoresced brightly. Reinhold (2020) found that her Platypus roadkill specimen fluoresced faintly. The two museum specimens briefly examined by the author showed almost no fluorescence, except for a faint dark green shimmer on the toes of one. The difference in fluorescence expression between the faint colour change in Reinhold's recently dead specimen and the strong glow of the American museum's long-dead specimen is counter-intuitive, suggesting other factors could be operating. For example, in the American specimens, fumigants required for exportation, may have led to a brighter fluorescence than elsewhere.

It is clear from even these limited observations that fluorescence is potentially widespread in Tasmanian marsupials and other mammals (pls 6–12). Where I have had the opportunity to compare museum specimens with freshly killed specimens, the differences are striking. For example, the Eastern Barred Bandicoot museum specimen displayed bright white and light blue ears but no colouration of the pelage, whereas two different freshly-killed specimens displayed an other-worldly, vibrant, almost shimmery orange-pink coat. This brilliant colour was most startlingly visible with the 395 nm torch but was also plainly discernible under 365 nm. While I am confident in my roadkill observations, it is possible that taxidermy chemicals and museum fumigants may give misleading results with fluorescence in museum specimens and this requires further study.

A NOTE ON FLUORESCENT BIRDS

Conceptually, luminous birds have been on the minds of scientists and philosophers for centuries (McAtee 1947). In the first century CE, for example, Pliny included luminous birds from the Black Forest of Germany in his *Naturall Historie* but suspected them to be an unfounded rumour (Pliny & Holland 1634). Later, during the Middle Ages, the German monk and naturalist Albertus Magnus included Pliny's birds with glowing wings, and Professor Conrad Gesner of Zurich, writing in *De Lunariis*, the first book devoted to luminescence, also included luminous birds without scepticism (Harvey 1957). In fact, as Harvey later wrote, "Practically all the great naturalists, and others who wrote in lighter vein, believed in luminous birds" (p. 67).

Strange and unexplained luminous phenomena have sometimes been attributed to birds, like the *Will-o'-the-Wisp* in England and the *Min Min* lights in Australia (Silcock 2006). *Will-o'-the-Wisp* is a phantom light floating in the air over swamps and bogs, supposedly leading travellers into trouble. *Min Min* lights are ghostly orbs seen hovering in the outback. These remain enigmatic questions to be answered by ecophysiologists, if not cryptozoologists.

While bioluminescence in birds is yet to be confirmed, fluorescence may in fact be relatively common. For example, Weidensaul *et al.* (2011) used it to routinely age the flight feathers of owls and observed that numerous species of owl tested by them and others all fluoresced. Similarly, Arnold *et al.* (2002) studied fluorescent signalling in Budgerigars *Melopsittacus undulatus* and a survey of nearly 1000 bird species, covering all orders, found high proportions exhibiting UV-reflecting feathers (Mullen & Pohland 2008). George Pohland studied the fluorescent plumage of two bird species from Tasmania, the Green Rosella *Platycercus caledonicus* and Orange-bellied Parrot *Neophema chrysogaster* (Pohland 2007) but did not provide details on their appearance under UV light.

Blythman *et al.* (2016) examined 74 Australian birds in six species (three Stringiformes and the remainder in the Caprimulgiformes), which fluoresced. Of these, the Tawny Frogmouth *Podargus strigoides* occurs in Tasmania, however, while the Australian Owlet-nightjar (*Aegotheles cristatus*) on the mainland fluoresces, whether the Tasmanian subspecies (*A. c. tasmanicus*) does, has yet to be tested. I only cursorily examined a few species of birds in a museum exhibition, and found fluorescence in eight, primarily in the feet and toes (table 2, pls 13–14). Whether this skin fluorescence was an artifact of the taxidermy process is unknown; but the findings are consistent with Stübel's (1911) observation that all biological tissues fluoresce. However, unexpectedly, a few other birds I tested for fluorescence with 395 nm UV did not produce any detectable result, including the Kookaburra *Dacelo novaeguineae* and the Eastern Rosella *Platycercus eximius*. The exhibition was lit, however, so a darker room or different wavelength of UV light may yield different results.

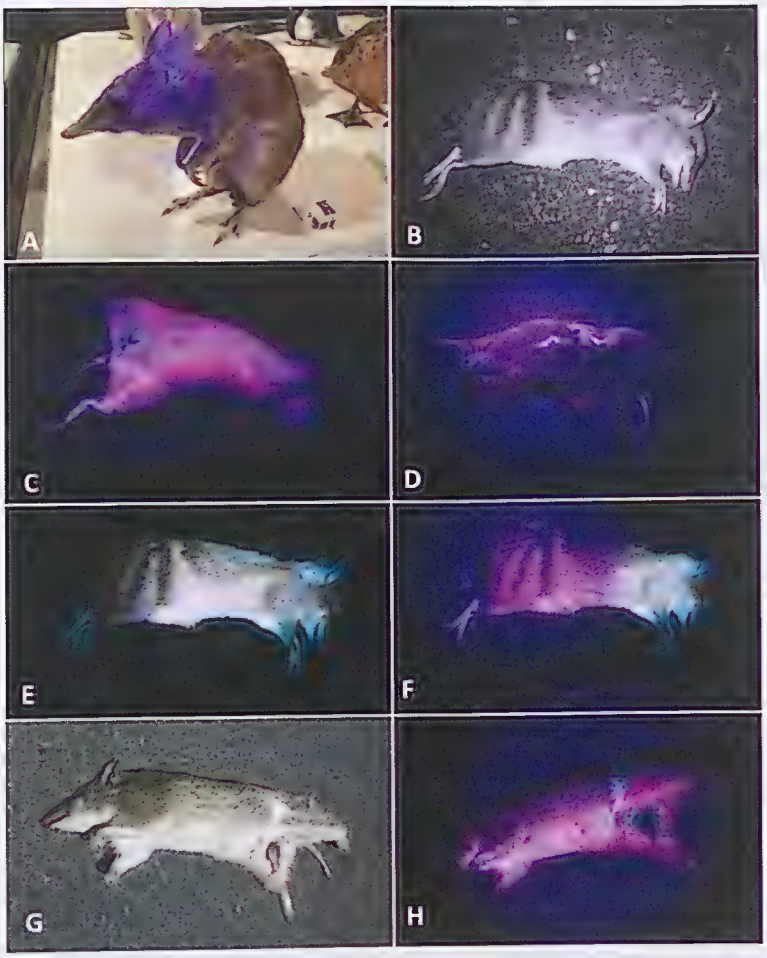

Plate 7 — Fluorescence in Tasmanian marsupials. **A–F** Eastern Barred Bandicoot *Perameles gunnii*; **G–H** Southern Brown Bandicoot *Isoodon obesulus*. A, museum specimen, note ears fluorescing blue under UV light. B-H, road-kill. B, G, white light, C-F, H, note intense fluorescence under UV light, C, D, H 395nm UV light; E, 365nm, F, 395nm on left and 365nm on right. Photos B-F copyright Luis Mora; A, G-H copyright Lisa Gershwin.

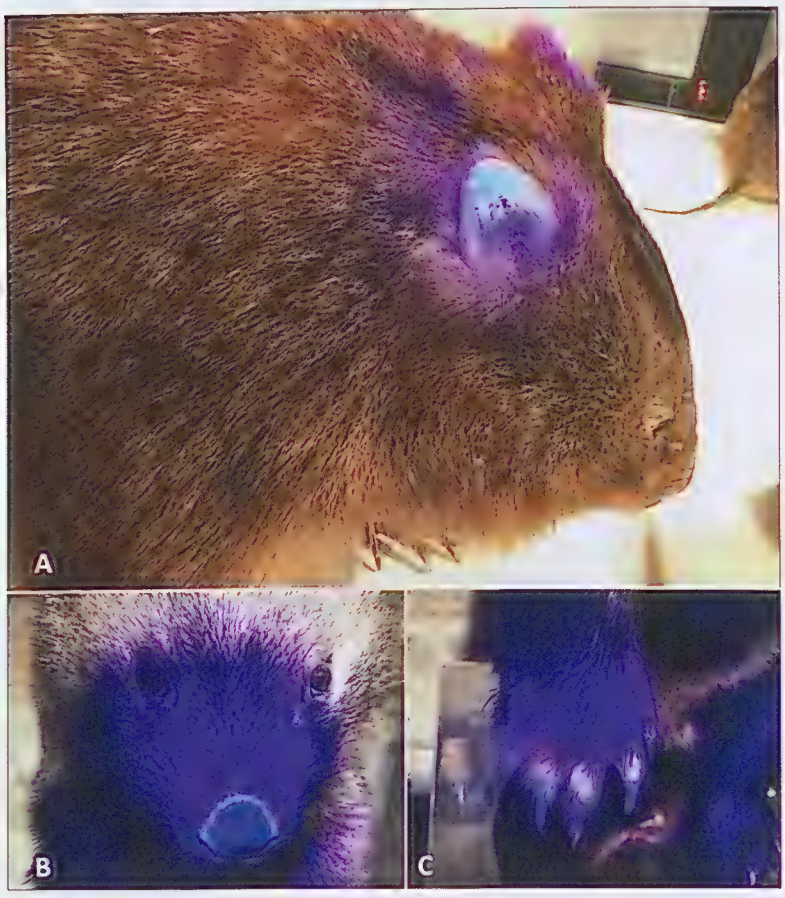

Plate 8 — Fluorescence in Tasmanian marsupials. Wombat *Vombatus ursinus*. Museum specimen, note turquoise and white fluorescing under UV light. **A** ears; **B** nose; **C** toes. All copyright Lisa Gershwin.

TABLE 1 — Summary of fluorescence in mammals found in Tasmania

Species	Fluorescence	Reference
Fluorescent Tasmanian Monotremes		
Platypus *Ornithorhynchus anatinus*	Bright blue-green fur and skin Some fur dull moss green Faintly dark green toes	Anich *et al.* (2021) Reinhold (2020) Museum specimen
Echidna *Tachyglossus aculeatus*	Bright whitish quills	Dr Kenny Travouillon Twitter 28 Nov. 2020; Museum specimen
Fluorescent Tasmanian Marsupials		
Tasmanian Devil *Sarcophilus harrisii*	Violet-blue ears	Readfearn (2020) Museum specimen
Eastern Quoll *Dasyurus viverrinus*	Violet-blue ears	Museum specimen
Spotted-tailed Quoll *Dasyurus maculatus*	Violet-blue ears	Museum specimen
Thylacine[1] *Thylacinus cynocephalus*	Bright blue bands on fur shaft under a fluorescent microscope; ? Turquoise ear, body and leg fur	Kean & Cutting (2022) Museum specimen
Eastern Barred Bandicoot *Perameles gunnii*	Light blue ears; Magenta belly, side fur, and between stripes on back; ears light blue	Museum specimen and roadkill
Southern Brown Bandicoot *Isoodon obesulus*	Orange-pink fur on underside, lighter on belly, deeper on thighs and biceps	Museum specimen and roadkill
Wombat *Vombatus ursinus*	Green fur; Light blue ears and skin around nose, white paws, dark green nose	Edwards (2020) Museum specimen
Brushtail Possum *Trichosurus vulpecula*	Sky blue skin; hairs many colours Blue hair Green fur Pink fur around face, neck, and belly	Bolliger (1944) Nicholls & Rienits (1971) ZIP (2018) Roadkill
Ring-tail Possum *Pseudocheirus peregrinus*	Brilliant white belly fur and white portion of tail, pale turquoise	Roadkill
Little Pygmy Possum *Cercartetus lepidus*	Turquoise ears and paws	Museum specimen
Krefts Glider *Petaurus breviceps*	Light blue fur on underside Turquoise ears and paws	Reinhold (2021a) Museum specimen
Bennetts Wallaby *Macropus rufogriseus*	Blue-green hind legs, dark blue paws, bright turquoise tail and inner ears	Roadkill
Pademelon *Thylogale billardierii*	Turquoise and white ears	Roadkill
Tasmanian Bettong *Bettongia gaimardi*	Pale blue ears, eye skin, mouth, and hind legs	Museum specimen
Fluorescent Tasmanian Placentals		
Lesser Long-eared Bat *Nyctophilus geoffroyi*	Turquoise ears and fur around eyes	Museum specimen
Broad-toothed Rat *Mastacomys fuscus*	Turquoise nose	Museum specimen
Swamp Rat *Rattus lutreolus*	Turquoise lower and upper lips, nose, inner ears, and penis	Museum specimen
Water Rat *Hydromys chrysogaster*	Turquoise lower lip and toes	Museum specimen
Long-tailed Mouse *Pseudomys higginsi*	Turquoise lower and upper lips and nose	Museum specimen

The extent to which the fluorescence in museum specimens was natural fluorescence or an artifact of the taxidermy process is unknown. [1] Indicates uncertainty, discussed in text.

A NOTE ON GLOWY MOSS

The luminescent moss *Mittenia plumula* (Mitt.) Lindb., often called "Goblin's Gold", was reported (https://www.facebook.com/groups/275373059316490/search/?q=Mittenia%20) from Loongana in Tasmania in November 2020 (pl 5c, 5d). Some debate about its identification and taxonomy followed on the website *iNaturalist* (https://inaturalist.ala.org.au/observations/64989974), leading the naturalist who posted it to withdraw the identification. The question remains unresolved. The species' luminescence, however, is somewhat misleading, attributable to refraction rather than true bioluminescence or biofluorescence.

In Australia, this moss is most often found in wombat holes, while it frequents rabbit holes in New Zealand, and in caves it sparkles and gleams over the ground as if numerous emeralds were scattered about (Glenny 2020). The New Zealand Biota website quotes a most lovely account of Goblin's Gold by Austrian botanist Anton Kerner von Marilaun (1887; translated by Crum (1973, p.147):

> *"If we reach curiously into the depth of the grotto to snatch a specimen of the shining objects and examine the prize in our hand under a bright light, we can scarcely believe our eyes, for there is nothing else but dull lusterless earth and damp, mouldering bits of stone of yellowish-grey color! Only on looking closer will it be noticed that the soil and stones are studded and spun over with dull green dots and delicate threads, and that, moreover, there appears a delicate filigree of tiny moss-plants. This phenomenon, that an object should only shine in dark rocky clefts, and immediately lose its brilliance when it is brought into the bright daylight, is so surprising that one can easily understand how the legends have arisen of fantastic gnomes and cave-inhabiting goblins who allow the covetous sons of earth to gaze on the gold and precious stones, but prepare a bitter disappointment for the seeker of the enchanted treasure; that, when he empties out the treasure which he hastily raked together in the cave, he sees roll out of the sacks, not glittering jewels, but only common earth."*

A NOTE ON OTHER GLOWY THINGS

An incredible diversity of Tasmanian species beyond those covered here are likely to fluoresce. Many amphibians fluoresce (Taboada *et al.* 2017, Lamb & Davis 2020, Reinhold 2021b), but to my knowledge none here have been tested. So too, a significant biodiversity of arthropods is already known to fluoresce, so it is possible that all terrestrial animal phyla are known to have at least one or more members that fluoresce (Lagorio *et al.* 2015, Jeng 2019), and that with further study these numbers may increase.

An emerging fascinating area of study is the co-occurrence of bioluminescence and biofluorescence (Jeng 2019). It seems that the cells involved with one often do double duty with the other. Given our range of bioluminescent species, it therefore seems plausible that some may also be fluorescent.

CONCLUSION

Tasmania's luminescent organisms offer an inherently fascinating way of understanding the natural world and the escalating pressures they face in a rapidly changing environment. Glow-worms are so susceptible to climate-related desiccation, fire smoke, food supply and human impact, that we may well lose them in the future. Glowing fungi may seem stable because their main fungal mass is hidden underground, but they require a delicate balance of moisture disrupted by climate warming as well as the burning of their habitat. Sea Sparkle, in contrast, is an

TABLE 2 — Summary of fluorescence in birds found in Tasmania

Species	Fluorescence[1]	Reference
Tawny Frogmouth *Podargus strigoides*	Hot pink flight feathers (underside) Turquoise toes	Blythman *et al.* (2016) Museum specimen
Galah *Eolophus roseicapilla*	Pale blue beak and skin around eyes	Readfearn (2020)
Masked Owl *Tyto novaehollandiae castanops*	Pale blue skin around eyes, base of beak, and feet; magenta feathers on underside of wings	Museum specimen
Wedge-tailed Eagle *Aquila audax fleayi*	Bright turquoise toes	Museum specimen
Lyrebird *Menura superba*	Pale blue toes and base of beak	Museum specimen
Cape Barron Goose *Cereopsis novaehollandiae*	Minty green feet	Museum specimen
Black Swan *Cygnus atratus*	Pale blue skin around eyes and beak (but unexpectedly, not the feet)	Museum specimen
Little Penguin *Eudyptula minor*	Light blue belly feathers and toe feathers	Museum specimen

[1] Whether the fluorescence observed in museum specimens was true fluorescence or an artifact of the taxidermy process is unknown.

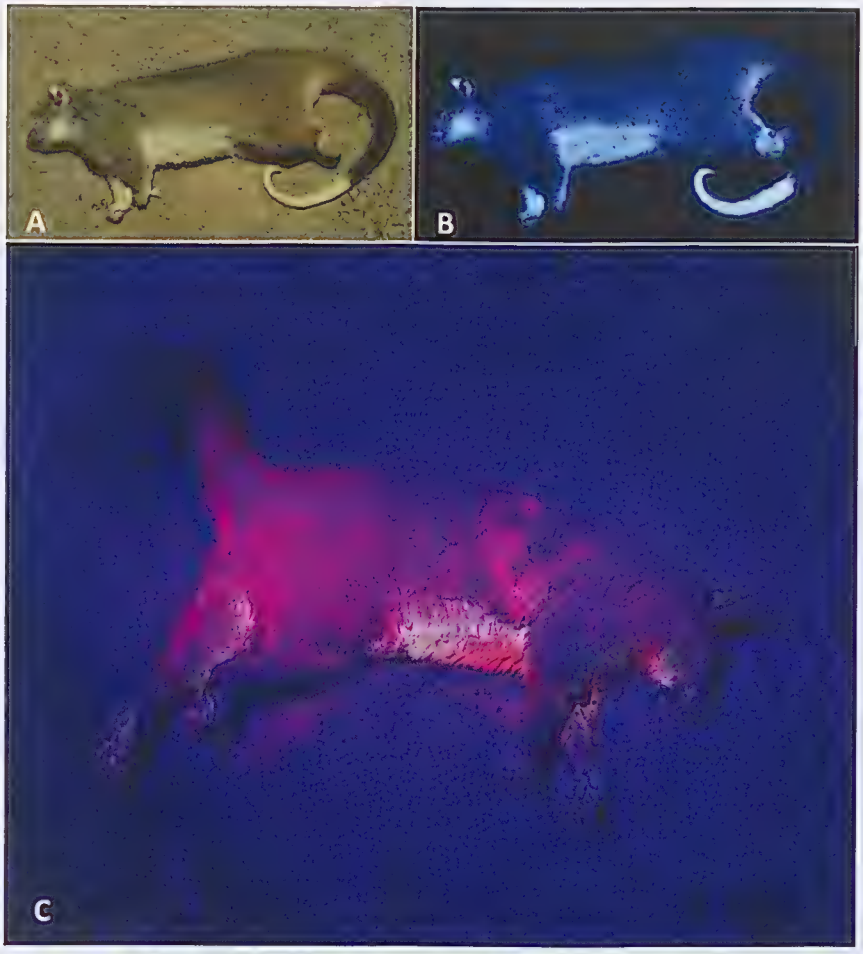

Plate 9 — Fluorescence in Tasmanian marsupials. **A**, **B** Ring-tail Possum *Pseudocheirus peregrinus*, Roadkill, note ears, belly, and white tail tip fluorescing bright white under UV light; **C** Brushtail Possum *Trichosurus vulpecula*, Roadkill, note body fluorescing pink under UV light. All three copyright Lisa Gershwin.

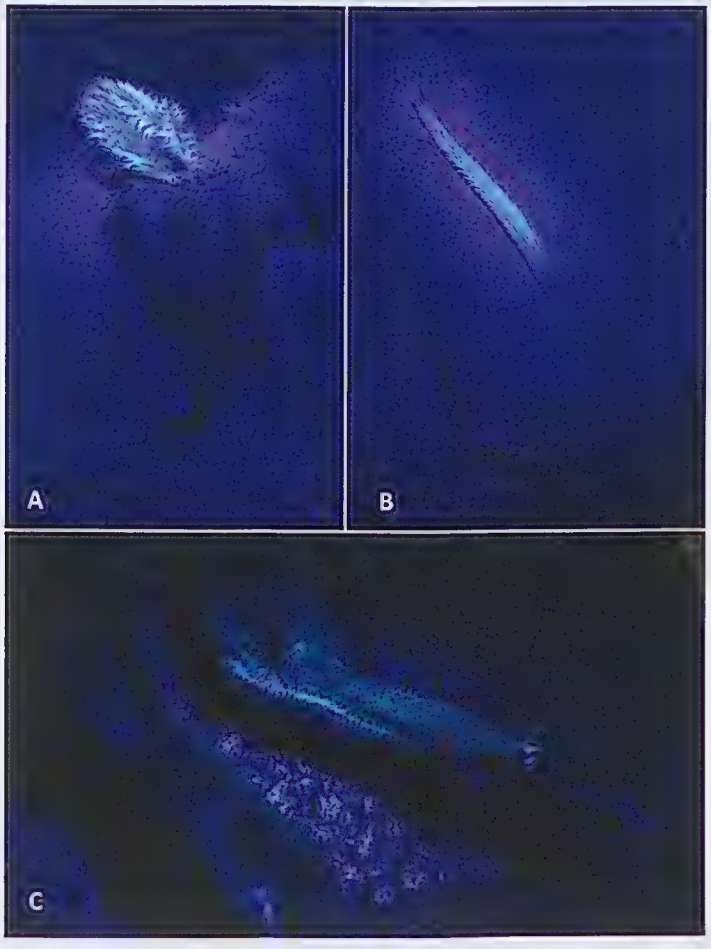

Plate 10 — Fluorescence in Tasmanian marsupials. Bennetts Wallaby *Macropus rufogriseus*. Roadkill. **A** Note fluorescing ear; **B** Note fluorescing tail; **C** Note legs fluorescing dark green under UV light. A, B copyright Lisa Gershwin C, copyright Toby Schrapel.

Plate 11 — Fluorescence in Tasmanian marsupials and monotremes. Museum specimens. **A** Krefts Glider *Petaurus breviceps*, note bright blue ears and paws fluorescing under UV light; **B**, **D** Pygmy Possum *Cercartetus lepidus*, note turquoise fluorescent ears and paws; **C** Echidna *Tachyglossus aculeatus*, note bright whitish fluorescent quills. All copyright Lisa Gershwin.

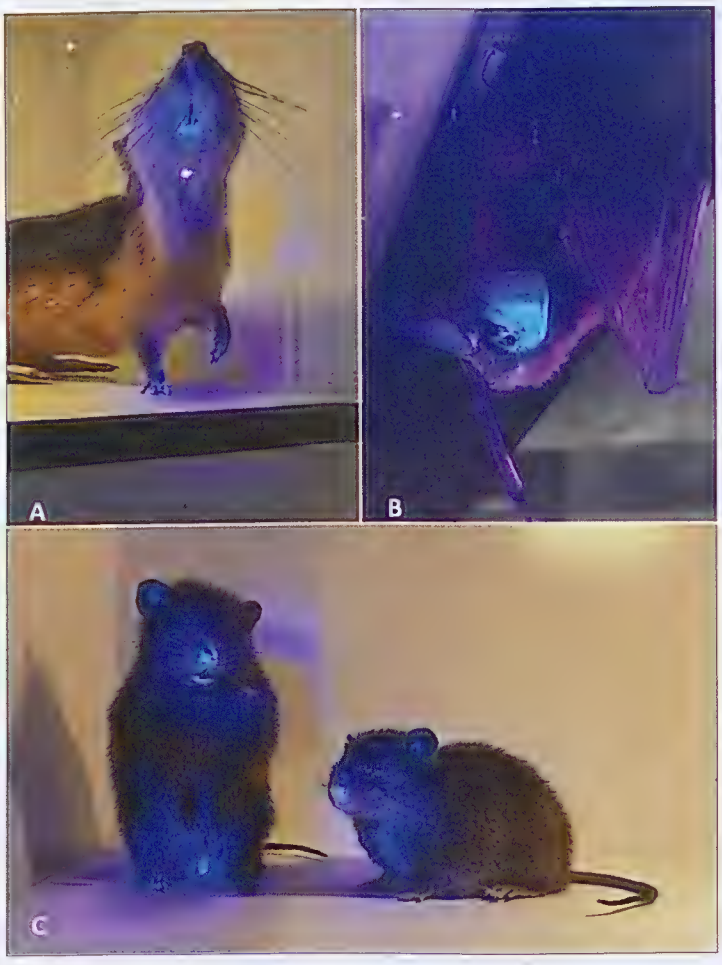

Plate 12 — Fluorescence in Tasmanian placental mammals. Museum specimens. **A** Water Rat *Hydromys chrysogaster*, note fluorescing face and feet; **B** Long-eared Bat *Nyctophilus geoffroyi*, note ear and eye fur fluorescing; **C** Swamp Rat *Rattus lutreolus*, note ears, nose, hind feet, and penis fluorescing turquoise under UV light. All copyright Lisa Gershwin.

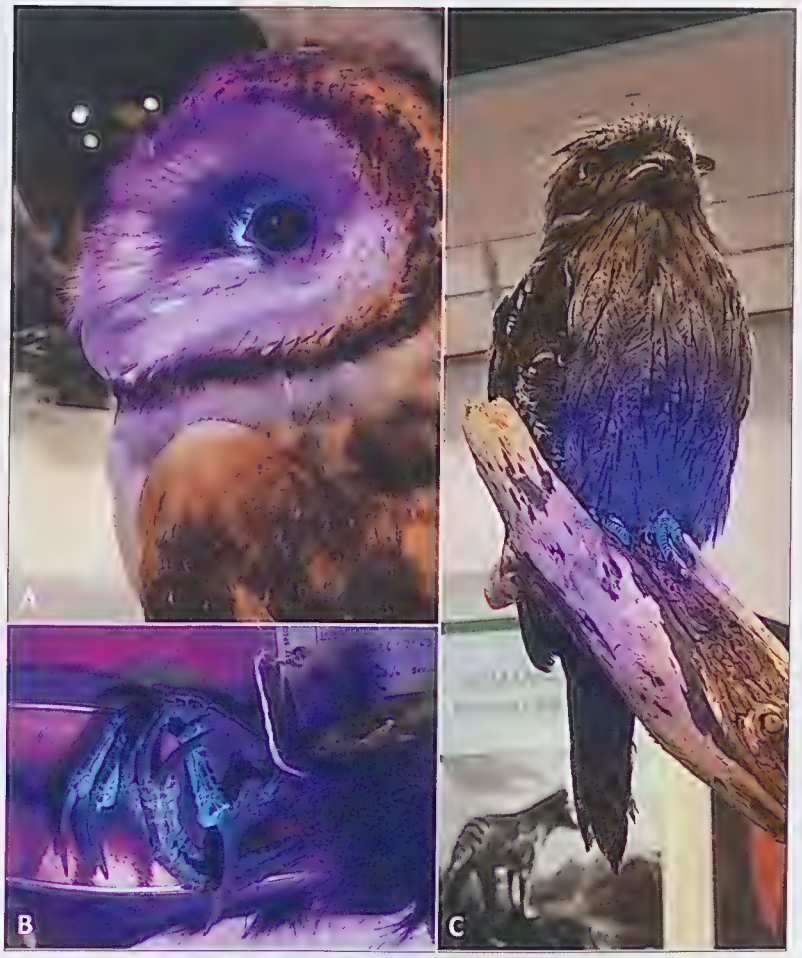

Plate 13 — Fluorescence in Tasmanian birds. Museum specimens. **A** Tasmanian Masked Owl *Tyto novaehollandiae castanops*; **B** Lyrebird *Menura superba*; **C** Tawny Frogmouth *Podargus strigoides*. Note UV light-stimulated pale blue fluorescence of skin around eye and upper beak in A, and of pale green fluorescence of feet in B–C. All copyright Lisa Gershwin.

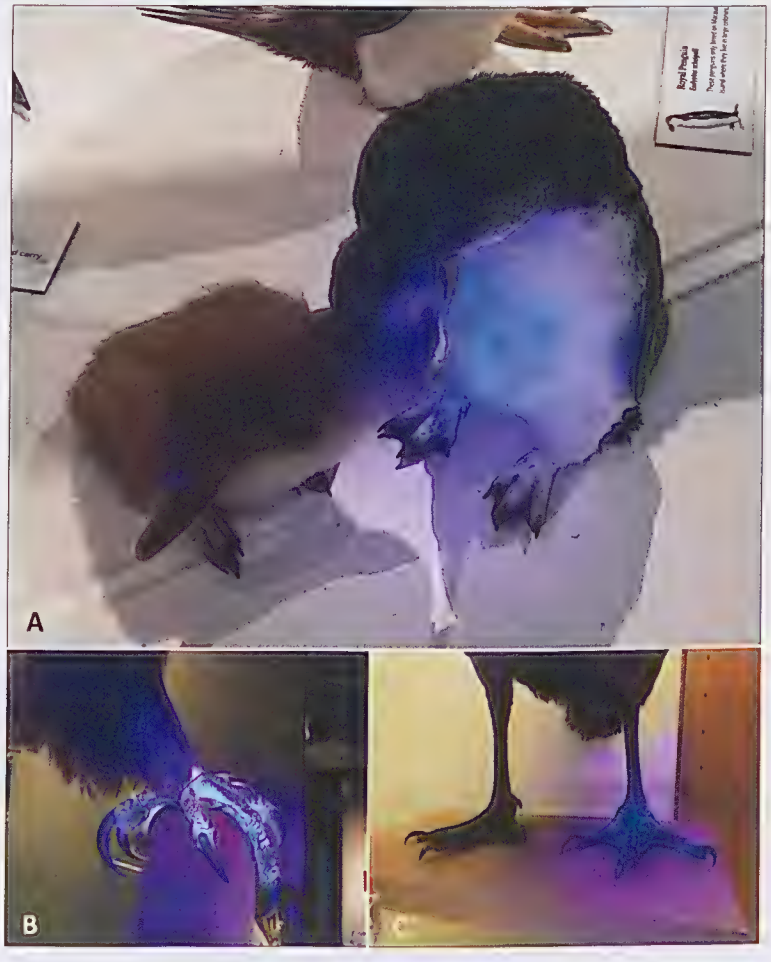

Plate 14 — Fluorescence in Tasmanian birds. **A** Little Penguin *Eudyptula minor*; **B** Wedge-tail Eagle *Aquila audax fleayi*; **C** Cape Barron Goose *Cereopsis novaehollandiae*. Note UV light-stimulated blue fluorescence of belly feathers in A, and of pale green fluorescence in feet of B–C. All museum specimens. All copyright Lisa Gershwin.

introduced marine pest which thrives in Tasmania's over-nutrified coastal ecosystems, and the wildlife carnage on Tasmanian roads speaks the truth about the fight our native animals are losing. Even scorpions and mosses, considered by most as unwanted pests, may garner appreciation when seen in this new light.

With new information emerging especially about fluorescent and bioluminescent organisms, we are very much at the dawn of understanding the glowing world around us. This is a wondrous age of adventures in luminescence that are in the grasp of citizen scientists and those who contribute to image-driven databases like *iNaturalist* or *QuestaGame* are not only having fun but helping build scientific knowledge to such an extent that they may rightly be considered parascientists.

ACKNOWLEDGMENTS

I am grateful to the Editor for encouraging me to write this paper, and to reviewers Linda Reinhold and Jenny De Jonge for generously improving the manuscript. I thank the American Geophysical Union for permission to use Robert Eather's evocative passage from *Majestic Lights* and the many photographers, citizen scientists and researchers who have assisted with information or allowed me to use their photographs, especially (in alphabetical order): Bronek Burza for the *Mycena* photos, Daniel Dirks for the glow-worm photo, Sophie Fazackerley for her splendid aurora image for the cover, Genevieve Gates for numerous fungi information, Jenny Kathy (Bioluminescence Tasmania) for so kindly sharing her insights and observations on Sea Sparkle and Ghost Mushrooms, Jo Malcolmson (Blackpaw Photography) for her amazing photos and videos, Brenda Marshall for her moss photo, Luis Mora and Toby Schrapel for numerous photos, Ryan Shan for *Panellus* photos, Margaret Sonneman for aurora information, Fiona Walsh (Gumboots Photography) for sharing the most incredible bioluminescence with me, Leena Wisby (Leena's Lens), Nick Dobinson, Luke O'Brien, and James Stone, for their generosity and stunning photos. In all aspects of luminous phenomena in Tasmania, citizen science activities such as photographers' interest and the sharing of information through Facebook groups have provided a wealth of information far outpacing the funding and execution of formal scientific study, and to them we all owe a debt of gratitude.

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(accepted 25 October 2022)

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